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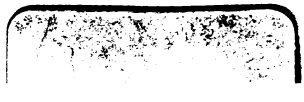

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PLEASING PRECEPTOR;

OR

FAMILIAR INSTRUCTIONS

IN

NATURAL HISTORY AND PHYSICS,

ADAPTED TO THE

CAPACITIES OF YOUTH,

AND CACULATED EQUALLY TO INFORM AND AMUSE THEIR MINDS DURING THE INTERVALS OF MORE DRY AND SEVERE STUDY:

TAKEN CHIEFLY FROM THE GERMAN

OF

GERHARD ULRICH ANTHONY VIETH,

MATHEMATICAL TEACHER AT DESSAW;

INTENDED FOR

THE USE OF SCHOOLS,

AND

ILLUSTRATED WITH CUTS.

VOL. II.

Simul et jucunda et idonea dicere vitæ.

HORAT. DE ARTE POET.

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THE

PLEASING PRECEPTOR;

OR,

FAMILIAR INSTRUCTIONS, &c.

CHAP. I.

OF THE COHESION OF WATER.

AS the former volume of our work commenced with the apparent ſwimming of a needle, and a thin bit of metal, we will here ſay a few words more on the ſame ſubject. Our young readers will recollect, it was there obſerved, that the needle did not properly ſwim, but was ſuſtained on the ſurface of the water, becauſe it's weight was not ſufficient to overcome the coheſion between the particles of the fluid. This may be ſeen clearly in the following little experiment, which any one may eaſily try.

Take a glaſs of water, and lay on it's ſurface a *bit* of leaf gold, or dutch metal.

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creature of ſuch bulk. Theſe birds frequent marſhy places, and the leaves and ſtems of the aquatic plants, that grow in the water, and lie along it's ſurface, no doubt, help to ſupport them, at the ſame time that they run ſwiftly; and the ſlight movement they make with their wings contributes to diminiſh their preſſure on the water.

CHAP. II.

OF ABSOLUTE AND SPECIFIC GRAVITY.

THE terms *abſolute gravity* and *ſpecific gravity* very frequently occur in phyſics. The firſt is what we expreſs in common life by the word *weight*, and ſignifies the whole of the power, with which a body preſſes downward to the Earth. Every particle in every ſubſtance is heavy; that is, it has a tendency to fall toward the Earth, or is attracted by the Earth. Now, the greater the number of particles a ſubſtance has, the more powerful will be it's tendency toward the *Earth: and* we expreſs the degree of this ten-

dency by certain quantities, on which we have fixed as ſtandards, by ounces, pounds, &c. Thus we ſay, rightly, this ſtone *weighs* ſo many pounds; that pound *weighs* ſixteen times as much as this ounce. It is very common, however, to ſay, that ſtone is as *heavy* again as this; that pound weight is ſixteen times as *heavy* as this ounce: but this, in a phyſical ſenſe, is improper; the two ſtones, if they be of the ſame kind, are equally *heavy*, for they would both fall to the ground from the ſame height in the ſame time; and ſo are the pound weight and the ounce, if they be of the ſame metal: their heavineſs, or gravity, is the ſame, but their weight is different.

Specific gravity expreſſes the relative idea of weight, as it regards the bulk of a body. Thus, a cubic inch of lead weighs more than a cubic inch of wood, and a cubic inch of cork weighs leſs: accordingly we ſay, the ſpecific gravity of wood is leſs than that of lead, and greater than that of cork. The ſpecific gravity of a body is in proportion to the denſity of the matter, of which it conſiſts; and thus we may judge of the denſity of a ſubſtance by it's ſpecific gravity. In lead, the

particles, that compoſe it, are cloſer together than in wood; while, in the wood, the interſtices between the particles are greater.

To denote the ſpecific gravity of any thing, it is uſual to aſcertain how much more, or leſs, a given bulk of it weighs, than an equal bulk of pure water; and, taking the weight of the water as an unit, to expreſs that of the other, by whole numbers, or a decimal fraction, or both. Thus, for example:

The ſpecific gravity of water being . . .	1.000
That of platina will be	21.000
Very fine gold . . .	19.637
Standard gold . . .	18.888
Quickſilver	14.019
Lead	11.325
Fine ſilver	11.087
Standard ſilver . . .	10.535
Copper	8.843
Steel	7.852
Iron	7.645
Block Tin	7.321
Diamond	3.400
Clear glaſs	3.150
White marble . . .	2.707
Green glaſs	2.620

weight of water, as is commonly done, for unity, we need only divide the loſſes found by the loſs in water. So

	B.	Divided by two.
The loſs in water	= 2	1.0000
milk	= $2\frac{1}{16}$	1.0312
beer	= $2\frac{1}{8}$	1.0625

"We will now vary the experiment, and endeavour to compare the ſpecific gravities of ſolid bodies with each other, by weighing them firſt in the air, then in water."

William collected different matters; a flint, a piece of brick, a bit of iron, and other things. The flint weighed ten ounces and $\frac{1}{8}$ in the open air; but when it was ſuſpended in the water, it was neceſſary to take four ounces out of the ſcale, to reſtore the equilibrium. Thus much, therefore, it loſt of it's weight.

F. "What do we learn from this loſs of weight in the ſtone?"

W. "The weight of the water that would fill the ſpace occupied by the ſtone."

F. "From this can we not eaſily compare the ſpecific gravity of the ſtone with that of water?"

W. "The ſtone weighs 10 ounces and $\frac{1}{8}$: an equal bulk of water would weigh four

There is a more accurate method, however, and at the ſame time more eaſy; and we ſhall ſee, in the next chapter, how William was led by his father to the diſcovery of this.

CHAP. III.

THE BUCKET IN THE WELL.

WILLIAM, one day, obſerved a man drawing a bucket of water out of a well. As long as the bucket was under water, the man turned the winch very eaſily; but as ſoon as the bucket was raiſed above it, much more exertion was required, and the rope wound ſlowly and heavily round the roller. "Why is this?" ſaid William to himſelf. He was aware, that the water in the bucket rendered it heavy, but he did not underſtand what occaſioned the difference in it's weight, and, therefore, aſked his father.

"What you have yourſelf obſerved," anſwered his father, "that the water renders the bucket heavy, is perfectly right; and you need only purſue this idea a little farther, to *obtain a clear* conception of that, of which,

will ſink only in part. Now, could we employ ſuch bodies as theſe, to find either their own ſpecific gravity, or that of fluids?"

William. "That is a queſtion, I am not yet prepared to anſwer."

F. "You do well, William: it is better to confeſs this, than to give any anſwer, that comes uppermoſt, as too many do, leſt the perſon who queſtions them, ſhould ſuppoſe, that they know nothing about the matter. I will endeavour, therefore, to lead you to the point. Why does a ſtone ſink in water to the bottom?"

W. "Becauſe it is heavier than an equal bulk of water, and conſequently does not loſe the whole of it's weight."

F. "If a body had juſt the ſame weight as an equal bulk of water, it would be completely immerſed in it, but would not ſink to the bottom; ſo that it would remain at reſt, wherever you choſe to place it, at the bottom of the water, in the middle, or at the top."

W. "That I conceive; for it would be juſt the ſame thing, whether the place were occupied by ſuch a body, or by water."

F. "Of this you may very eaſily convince yourſelf. Take a bit of wax, make a ball of it, and thruſt into it as many ſmall ſhot, as

will make it weigh exactly as much as the water, that would occupy it's ſpace; you will then be able to place it in any part of the veſſel of water, without it's either riſing or ſinking."

William tried the experiment, and found it ſucceed.

F. "Now, as the preſſure upward of the ſurrounding water equals the weight of the water diſplaced by the immerſed body, or that which would fill the ſpace this body occupies, what would be the conſequence, if a body of a lighter kind, as a piece of wood, were completely immerged?"

W. "It would be forced upward by the ſurrounding water."

F. "Why?"

W. "Becauſe the weight of the water diſplaced, conſequently the preſſure of the ſurrounding water, exceeds the weight of the wood."

F. "The two powers, that are oppoſed to each other, then, are the whole abſolute weight of the wood, which preſſes downward, and the preſſure of the ſurrounding water, acting upward. When, therefore, will the *wood remain at reſt?*"

ſuſtains, as we have ſhown, juſt as much, as the water, that would fill the ſpace, would weigh. Whether lead, or ſtone, or any other ſubſtance, occupy this ſpace, does not affect the preſſure of the ſurrounding water; this preſſure is proportionate to the dimenſions of the ſubſtance, not to it's weight."

W. "That is clear."

F. "Well, then; if we weigh a body in an accurate pair of ſcales in the open air, and then let the body thus weighed be ſuſpended in a veſſel of water, will it require an equal weight to counterpoiſe it as before?"

W. "No; for the water ſupports part of the weight."

F. "And how much this is, or how much of it's weight it will loſe, you already know."

the latter; namely, juſt as much as the whole weight of the body partly immerſed."

F. "Conſequently it's ſpecific gravity muſt be double: and ſo in every other caſe. The leſs ſpace of a fluid is neceſſary, to obtain a given weight, the greater muſt be the ſpecific gravity of the fluid: or, as it is commonly expreſſed, *in equal weights, the ſpecific gravities are in the inverſe ratio of the ſpaces occupied by the bodies.* Is this clear to you?"

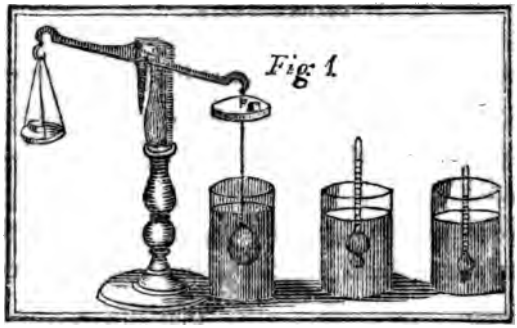
W. "Perfectly."

F. "On this principle are conſtructed the inſtruments called *hydrometers*, which are uſed to prove or aſcertain the ſtrength of ſpirits, try the ſtrength of wort, and examine the ſaturation of brine in ſalt-works. The deeper the hydrometer ſinks in ſpirits, the better they are: in worts and brine, the contrary."

W. "How are theſe hydrometers conſtructed?"

F. "They are commonly hollow balls of glaſs, with a ſmaller ball, containing quick-ſilver at bottom, and a ſlender tube at the top. The tube, or ſtem, is graduated, that the depth, to which it ſinks, may be known.

time Mr. Goodwin got ready his hydroſtatical balance, which our readers will ſee delineated in the vignette underneath.



This balance is conſtructed on the ſame principle as a common pair of ſcales: the tongue, however, does not riſe perpendicularly from the beam, but points perpendicularly downward. To one a rinhangs a ſcale, which is to contain the weights; from the other is ſuſpended the body, which is to be weighed in the fluid. It is neceſſary, that ſuch a balance ſhould be very accurate, and very ſenſible, or capable of turning with a very minute weight, otherwiſe ſlight differences would not be perceived. The axis of the beam, on which it reſts, has a ſharp edge, to render it's friction as ſmall as poſſible.

To find the ſpecific gravity of different fluids, a glaſs egg, containing a little quick-

in the proportion of 10, 9, 8, nearly as water, oil, and ſpirit of wine. In water, the ſpecific gravity of which we take as ten, the hydrometer ſinks to this point, which I mark on the ſtem: now, will it ſink deeper, or leſs deep, in a fluid of the ſpecific gravity of 9?"

W. "It will ſink deeper."

F. "I have already obſerved, that the bulks immerſed are in the inverſe ratio of the ſpecific gravities, or denſities; the weight of the inſtrument, and conſequently of the fluid diſplaced, remaining the ſame. How then will you calculate the depth, to which the hydrometer muſt ſink in the ſecond fluid?"

W. "I ſhould calculate thus: as 9 is to 10, ſo muſt the bulk immerſed in water be to the bulk immerſed in oil."

F. "Very right. If, therefore, I would ſink the inſtrument as deep in water, as it would ſink ſpontaneouſly in oil, muſt I not add more weight to it?"

W. "Certainly."

F. "But how is the weight required, to ſink the inſtrument as deep in water, as it would ſink of itſelf in oil, to be found?"

This William was not able to anſwer immediately.

F. "You have already ſaid, that the parts immerſed muſt be as 9 to 10: if, therefore, we would ſink the inſtrument in water in both theſe degrees, muſt not the weight of water diſplaced in the two inſtances be as 9 to 10?"

W. "To be ſure."

F. "And conſequently the weight of the inſtrument at firſt to it's weight when increaſed as 9 to 10?

W. "So I conceive."

F. "You are now able to tell me how much the original weight of the inſtrument muſt be increaſed?"

W. "A ninth part."

F. "Now, if we take the third fluid, the denſity of which is to water as 10 to 8, how muſt we proceed?"

W. "As before. The bulks are as the inverſe ratios of the denſities, the weight of the inſtrument remaining the ſame; that is, as 8 to 10."

F. "And If I would ſink it ſo deep in water, to mark the degree, how ſhould I find the weight, to be added to the inſtrument?"

W. "The original weight muſt be to the *increaſed* weight as 8 to 10; or the original

weight muſt be increaſed by the addition of $\frac{1}{3}$ or $\frac{1}{4}$."

F. "Thus we have found a method of marking on the ſtem of the hydrometer degrees, that will give the *proportions of denſities*, or ſpecific gravities. Namely: the hydrometer is firſt to be weighed as accurately as poſſible in the air: it is next to be immerſed in water, and the point to which it ſinks is to be marked: and then the weight of the inſtrument is to be increaſed by the addition of $\frac{1}{9}$, $\frac{1}{8}$, $\frac{1}{7}$, and ſo on, marking each time the depth to which the ſtem ſinks. Thus we have the hydrometer graduated for fluids, that are lighter than water, and the degrees may be marked in an aſcending ſcale, 0, 1, 2, 3, &c. In this caſe, when the hydrometer ſinks to 0, the ſpecific gravity of the fluid is as 10, or 1.0; when to 1, as 9, or 0.9; when to 2, as 8, or 0.8; when to 3, as 7, or 0.7; and ſo on.

"I have taken theſe numbers, that you might find leſs difficulty in the inveſtigation; but in practice much ſmaller diviſions are required. Inſtead of denoting the ſpecific gravity of water *by 10*, we might take it at 100, *and increaſe the* weight of the hydrometer

by $\frac{1}{95}$, $\frac{2}{95}$, $\frac{3}{95}$, $\frac{4}{95}$, and ſo on; markng theſe ſmaller degrees on the ſtem as before, from below upward, with 0, 1, 2, 3, 4, &c.

"In this caſe, when the hydrometer ſinks to 0, the ſpecific gravity of the fluid is as 100, or 1.00; when to 1, as 99, or 0.99 when to 2, as 98, or 0.98; and ſo of the reſt If the inſtrument be large enough, the diviſions may be made to thouſandth parts but I need not go farther, as, no doubt, you already ſee how the proceſs is carried on."

W. "I ſee, it is true."

F. "But, you would ſay, you have it not all clear before your eyes. The fact is, my dear William, things that require ſome reflection, ſhould be gone over more than once from the begining, that the whole chain of reaſoning may make a more diſtinct impreſſion on the mind. Sit down, therefore, and write all that you have retained; you will find this a good exerciſe both of your memory and reflection."

William immediately followed his father's advice, and took the ſame method on other occaſions. Many of our young readers, we *hope, are not* averſe to reflection, and will do *the ſame.* That they may be the more read

to purſue this plan, they ſhould bear in mind, that it's utility is not confined to the caſe that they may have in hand. To inſtance in the preſent example: the uſe of conſidering and weighing thoroughly the doctrine there given reſpecting the hydrometer, though it is pleaſing to know more of ſuch a common inſtrument, and be better acquainted with it's principles, than moſt who uſe it, does not ſtop here; for, by it the mind acquires a degree of facility in forming juſt conceptions, making proper compariſons, and drawing right concluſions, in ſimilar caſes; and, even, in all caſes, the habit of reflection is ſtrengthened and improved by it. The propoſitions of *hydroſtatics*, ſo the ſcience of the equilibrium of fluids is called, are particularly calculated to exerciſe reflection; we will, therefore, purſue the converſation between William and his father a little farther.

CHAP. VII.

CONTINUATION.

Father. "We found yeſterday how an hydrometer for lighter fluids was to be graduated, ſo as to ſhow the proportions of dif-

ferent ſpecific gravities; but how ſhould we proceed for heavier fluids?"

William. "No doubt in the oppoſite way."

F. "You mean, that the weight of the inſtrument muſt be gradually diminiſhed. Suppoſe we wanted the hydrometer to indicate ſpecific gravities proportioned to another as 100 to 101, taking the firſt for that of water, we muſt here proceed as follows:

"The part of the hydrometer immerſed in water muſt be to that immerſed in the heavier fluid as 101 to 100, or in the inverſe ratio of their ſpecific gravities. If the inſtrument were to be immerſed in water no deeper than in the heavier fluid, the weight of the water diſplaced muſt be to that ordinarily diſplaced by the inſtrument as 100 to 101: for which purpoſe the original weight of the inſtrument muſt be proportionally diminiſhed. What follows from this?"

W. "The original weight muſt be diminiſhed $\frac{1}{101}$."

F. "So, if we would find the point for a ſpecific gravity of 102, the original weight of the hydrometer muſt be to it's diminiſhed weight as 102 to 100. Conſequently ——"

W. "The original weight muſt be diminiſhed $\frac{2}{101}$."

F. "I need not proceed any farther, as you muſt be aware, that the degrees for other ſpecific gravities muſt be determined in the ſame way. Thus, if a 0 be put againſt the place, to which the hydrometer ſinks in water, and the other degrees be marked in a deſcending ſeries 1, 2, 3, and ſo on, theſe degrees will mark proportional diminutions in the ſpecific gravity of fluids: 0 being equal to 100, or 1.00; 1, to 101, or 1.01; 2, to 102, or 1.02; 3, to 103, or 1.03."

W. "But it ſeems to me, that it muſt be very difficult, to divide an hydrometer accurately in this way."

F. "You are very right, for great nicety is required, to increaſe the weight of the hydrometer preciſely $\frac{1}{99}$, $\frac{2}{99}$, $\frac{3}{99}$, or to diminiſh it $\frac{1}{101}$, $\frac{2}{101}$, $\frac{3}{101}$, and ſo on.

"In fact, if we did not think much of the trouble of a little calculation, we might go to work in a much more certain way. We need only make an hydrometer with a little cup at the top, into which we might put weights, to ſink it to a given depth in all fluids. Thus, if I had an hydrometer weighing exactly 500 *grains*, I ſhould make a mark on *the ſtem, to which* it ſhould always be im-

merſed. Now, ſuppoſing, that I muſt put in the cup thirty grains, to ſink the hydrom ter to this mark in pure water; the wat diſplaced would weigh 530 grains: ſuppoſi too, that ſixty grains would be required, ſink it to the ſame mark in a ſolution of ſa the brine diſplaced muſt weigh 560 grai Conſequently, as an equal bulk of the inſtr ment was immerſed in both caſes, the ab lute weights of fluid diſplaced muſt be 530 to 560; and, as it is uſual, to take t weight of pure water as the unit, or ſtanda we have only to calculate, by the rule of p portion, as 530 is to 560, ſo will one be the ſpecific gravity ſought.

530)560(1.056
530
3000
2650
3500
3180
320

"This is evidently a better way of p *ceeding, than* the troubleſome, yet not cer *method of* graduating the ſtem."

W. "Why, then, do people graduate the ſtem?"

F. "Becauſe, when once the inſtrument is finiſhed, no farther calculation is required; nothing more being neceſſary, every time you uſe it, but to read the degree marked on the ſcale, which is certainly the eaſieſt way. Different hydrometers have been conſtructed, in which both theſe methods have been united to a certain degree; but for thoſe, who wiſh for the greateſt poſſible nicety, far the beſt is that invented by Mr. Nicholſon, on the principle above mentioned, which is ingeniouſly contrived to determine the ſpecific gravities of ſolids alſo.

"Now you have thus gone through the conſtruction of the hydrometer, you will probably find the following ſtory both inſtructive and entertaining."

CHAP. VIII.

THE CHEAT DETECTED.

F. "ABOUT two hundred and fifty years before Chriſt, a celebrated mathematician *lived at Syracuſe,* named Archimedes, whoſe *inventions and writings* were of great ſervic

to his fellow citizens, as well as to the ſcience. This ancient may be called the father of hydroſtatics, for he wrote, among his other works, a book on bodies that ſwim in water. The ſtory, with which I am now going to acquaint you, is not to be found in what we have of this book however, but in another ancient work, in Vitruvius on Architecture. Many, indeed, hold it to be a fable, becauſe it is not come down to us in the writings of Archimedes himſelf: but certainly this is not a ſufficient reaſon for deeming it untrue, particularly as we have not the works of Archimedes entire. At any rate, it is neither improbable in itſelf, nor unworthy of the man. If you have any inclination to try whether you underſtand latin enough to tranſlate it yourſelf, reach me down that great book."

William was very ready to do this, as he had found, on more occaſions than one, that there were many things new to him in ſimilar old books. Accordingly, having taken down Vitruvius, and turned, as he was directed, to the third chapter of the ninth book, with his *father's* aſſiſtance he read as follows.

"Among the various and admirable inventions of Archimedes, the following appears to me the moſt ingenious.

"When Hiero of Syracuſe was exalted to the throne for the rectitude of his conduct, he reſolved to dedicate a crown of gold to the immortal gods. Having agreed with a goldſmith for the fabrication of this crown, the due quantity of gold was accurately weighed, and delivered to him. At the appointed time the crown was finiſhed; the king was ſatisfied with the workmanſhip; and the weight was found to be juſt. It was not long, however, before a report was ſpread, that the workman had purloined a portion of the gold, and ſubſtituted ſilver in it's place.

"Conſidering his own honour involved in the queſtion, Hiero was greatly incenſed, but knew not how the truth was to be diſcovered. Accordingly he referred it to Archimedes.

"While Archimedes was endeavouring to deviſe ſome means of detecting the cheat, he one day obſerved, as he was going into the bath, that the water flowed over the brim, in proportion to the ſpace occupied by his *body. This inſtantly* ſuggeſted to his mind

a ſolution of the problem; and, overcome with joy, he ſprung out of the bath, and ran home, naked as he was, crying, as he ran, 'I have found it! I have found it!'

"In conſequence of this diſcovery, we are informed, he took two maſſes, one of gold, the other of ſilver, each exactly equal in weight with the crown; filled a veſſel to the brim with water; and let the maſs of ſilver down into the water by a ſtring. Of courſe a quantity of water ran over, equal to the ſpace the ſilver occupied. Then, having drawn out the ſilver, he meaſured the water, that had run over, and poured it in again, ſo that the veſſel was filled to the brim as before. Hence he calculated how much water anſwered to a given weight of ſilver. This being aſcertained, he let down the maſs of gold into the full veſſel, in the ſame manner, and, after he had taken it out, meaſured the water that had run over. This, he found, was not equal to the former quantity, but ſo much leſs as the maſs of gold was leſs than the maſs of ſilver of equal weight. Having filled the veſſel a third time, he put in the crown itſelf; and it appeared, that more water ran *over, than had* done on the immerſion of an

equal weight of gold. From the quantity of water, that ran over when the crown was put in, more than the maſs of gold cauſed to overflow, he found by calculation the weight of the ſilver mixed with the gold, and thus the cheat of the goldſmith was detected."

F. " So far Vitruvius. I muſt obſerve to you, however, that Archimedes took it for granted, in his experiment, that gold and ſilver melted together would occupy juſt the ſame ſpace, as the two unmixed: but this was an errour. In moſt caſes of melting metals together as well as in ſolutions, and mixtures of other kinds, the compound occupies leſs ſpace than the ingredients would have done ſeparately, one of the ſubſtances penetrating into the interſtices of the other.

" If gold and ſilver did not penetrate each other, the adulterated crown would have been larger, and Archimedes would have found, that the goldſmith had employed more ſilver, than his experiment led him to conclude. But in fact the crown was leſs, than it ought to have been on his hypotheſis; ſo that he eſtimated the ſilver below it's real quantity, doing the *goldſmith* no wrong at leaſt by his *ingenious diſcovery.*"

CHAP. IX.

HOW MUCH SILVER WAS THERE IN THE CROWN?

Father. "VITRUVIUS, whoſe account you have juſt read, merely ſays, that the crown coſt a vaſt ſum of money; *immani pretio* are his words; but he gives us no information concerning it's weight, or the calculation of Archimedes. If, however, you would go through the experiment of Archimedes, we might ſuppoſe, that the crown weighed twenty pounds, and the water it diſplaced weighed one pound and a quarter: could you not find from this the difference of ſpecific gravity between the water and the crown?"

William. "As the crown weighed 20lb, and the water, that occupied the ſame ſpace, weighed 1¼lb, I have only to divide 20 by 1¼, and the quotient, which is 16, informs me, that the mixed metals weighed 16 times as much as an equal bulk of water."

F. "You may remember the difference between gold, and ſilver, and water, when we

were on the ſubject of ſpecific gravity the other day [p. 5]; but, as an arbitrary proportion will anſwer our purpoſe of explaining the experiment of Archimedes equally well, we will take it in round numbers, reckoning gold twenty times as heavy as water, and ſilver ten times as heavy. Thus, when Archimedes immerſed 20lb. of gold in the water, how much water was diſplaced?"

W. "One pound."

F. "And when he immerſed twenty pounds of ſilver?"

W. "Two pounds of water."

F. "Well, now we have to find how to compoſe a maſs of gold and ſilver, which ſhall weigh twenty pounds, and diſplace a pound and a quarter of water; in doing which we may reaſon thus.

"Mere ſilver we muſt not take, as it would diſplace three quarters of a pound of water too much. Is this evident to you?"

W. "Yes; for mere ſilver would diſplace two pounds of water, which are three quarters of a pound more than were diſplaced by the mixed maſs."

F. "And mere gold we muſt not take, for——"

W. "That would displace a quarter of a pound too little."

F. "Should we then take equal parts of each?"

William considered a little, without venturing to answer, for he was at a loss to know how to calculate.

F. "A little calculation will show us, that this would be wrong. Suppose I took ten pounds of silver, how much water would they displace?"

W. "One pound."

F. "And ten pounds of gold?"

W. "Half a pound."

F. "The whole twenty pounds of the mixture, therefore?"

W. "A pound and half. But this could not be the mixture, as it displaced only a pound and a quarter."

F. "We must proceed in some other way, then; and, I believe, it will not be difficult to find the right. Attend to what I say, and tell me what you think.

"The quantity of gold, that we must take, would displace less water, than a piece of the mixture of equal weight. Is it not so?"

W. "Certainly."

F. " But the ſilver, that we muſt take, would diſplace more water than an equal weight of the mixture would diſplace."

W. " That is very clear."

F. " Well, then, if we were to take gold and ſilver in ſuch proportions, that the deficiency in one caſe ſhould be equal to the ſurplus in the other, would they not balance each other? and would not the two together diſplace juſt as much water as the goldſmith's mixture?"

" I have found it! I have found it!" exclaimed William joyfully, in imitation of Archimedes.

F. " It is as good as found, indeed: but be not too haſty. Archimedes, when he leaped out of the bath, had probably advanced as far as we have done: but the laſt ſtep of the proceſs was to be performed in his ſtudy, and we muſt follow his example. How then muſt I proceed, to take a due proportion of gold, and a due proportion of ſilver?"

W. " So that the deficiency of water, diſplaced by the gold, may be ſupplied by the greater quantity, that the ſilver diſplaces."

F. " But twenty pounds of gold diſplaced a quarter of a pound too little, and twenty

pounds of ſilver diſplaced three quarters of a pound too much: was it not ſo?"

W. "We found it ſo juſt now."

F. "In equal weights, then, of gold, of ſilver and of the mixture, whether they weigh each twenty pounds or not, the difference between the quantities of water diſplaced by the mixture and by the ſilver is three times as great as the difference between the quantities diſplaced by the mixture and the gold?"

W. "Certainly."

F. "Well then, if we take three times as much gold as ſilver, how will the differences be?"

W. "They will be equal."

F. "The gold and ſilver muſt be taken then, in the inverſe ratio of their difference; and thus, in our caſe, we muſt take three pounds of gold to one pound of ſilver. You can now calculate the quantities, I ſuppoſe."

W. "Yes. Three pounds of gold and one of ſilver make four pounds; ſo the mixture muſt be three fourths gold, and one fourth ſilver. One fourth of twenty is five, and three fourths of twenty are fifteen: accordingly there muſt have been fifteen pounds *gold, and five* of ſilver."

CHAP. X.

THE WONDERFUL BALLS.

Henry to William.

" I received much pleaſure, my dear brother, from the deſcription, in your former letter, of the ſimple and judicious method of removing a houſe. What the mechanic is capable of effecting by means of machines is certainly wonderful: and if the nature of his materials, and the place on which he is forced to ſtand, did not preſent him obſtacles inſurmountable, his mediate powers would be unlimited. Archimedes ſaid to the king of Sicily, when ſtruck with aſtoniſhment at the effects produced by his machines: 'give me but a place out of the Earth to ſtand on, and I will move the World.' The expreſſion was certainly ſtrong; and Archimedes well knew, that it was impoſſible to conſtruct wheels and a lever capable of executing the gigantic thought. The king might have anſwered, 'I cannot give you what you require to move the Earth, it is true; but, if

Theſe caught hold of the prows of the ſhips, raiſed them up on their ſterns, and then ſuddenly let them fall. The terrible ſhock a ſhip muſt receive, thus falling from the height of the wall, with all it's men, and all it's ſtores on board, may readily be imagined. If haply it fell ſtraight into the water again, the violence of the fall immediately engulfed it in the waves.

"Marcellus was now convinced, that he could do nothing on the ſide of the ſea, and therefore drew off his forces from this part, that he might make a more powerful attack by land. But here likewiſe every place was amply ſupplied with the means of reſiſtance. The fortifications, on which Hiero had for many years employed every care, and much coſt; the works, which the incomparable art of Archimedes had erected; and a ſituation ſtrong by nature; favoured the defence, and fruſtrated the attack. The foundations of the walls were fixed on a ſteep rock. This gave the beſiegers the advantage, that their miſſile weapons were diſcharged with more certainty of execution, and blocks of ſtone, *rolled down*, made great havock among the *enemy*, wherever they ventured to approach.

pound produced only five balls, though theſe weighed as much as the former ſix. Thus it was apparent, that the particles of the melted tin muſt have inſinuated themſelves completely into the interſtices of the melted copper.

" Probably you wiſh to know more of Archimedes. If you requeſt our father, to let you tranſlate the 34th chapter of the 24th book of Livy, you will the refind many things reſpecting him, that will afford you much gratification.

" Farewell, my dear brother, and let me ſoon have the pleaſure of reading another letter from you."

" H. G."

CHAP. XI.

A FRAGMENT OF LIVY.

THE paſſage in Livy, which William was eager to peruſe on the recommendation of his elder brother, will not be unentertaining, we imagine, to our young readers.

" *The city of* Syracuſe was beſieged, both

of the ſtory may have originated from a miſconception, or a fault of ſome tranſcriber, which will readily account for it. It is not difficult to imagine, that Archimedes may have burned the roman ſhips by means of darts or arrows carrying fire; which was certainly more eaſy, than to ſet fire to them by means of burning-glaſſes. Were this the fact, ſome latin author perhaps may have related, that the ſhips were burned *ſpiculis ardentibus*, and ſome tranſcriber may have written *ſpeculis ardentibus*, inſtead of thoſe words,

CHAP. XII.

THE BENDING STEEPLE SET UPRIGHT.

WILLIAM was filled with admiration of the great artiſt, whoſe genius baffled the efforts of a mighty army. He formed to himſelf ſuch a lively idea of a huge iron hook deſcending from the wall, catching hold of a ſhip, lifting it up into the air, and again letting it fall, ſo as to daſh every thing in it to pieces, that he made a drawing of it, as like

himſelf had been preſent, and which we would lay before our readers, could we anſwer for it's accuracy. In many books, it is true, we find repreſentations of things, which the artiſt never beheld; but this is a liberty, in which we will not indulge, as it can lead only to erroneous ideas: we leave it, therefore, to every one's own imagination, to figure to himſelf the ſhips, the engines, and the perſon of Archimedes.

"This is ſomething more than removing a ſtable!" ſaid William, when he got to the end of the chapter.

"Certainly:" anſwered his father, who had aſſiſted him in his tranſlation from Livy. "But I could tell you of other performances by means of mechanics, both in ancient and modern times, at which perhaps you would not be leſs ſurpriſed."

W. "Will you tell me ſome of them? You know, I like to hear ſuch things."

F. "Very willingly: but firſt let me aſk, do you remember the chief laws of the lever, the pully, and the inclined plane, which I lately explained to you?"

William had written down theſe, that he might look at them occaſionally, to improve

them in his memory, and knew the heart.

W. "In the lever, and all machine ſtructed on the principle of the lever, a ſtans, winches, wheelwork, &c., to pr an equilibrium, the power and the v muſt be in the inverſe ratio of their di from the centre of motion; that is, inv as lines drawn from the centre of motio pendicularly to the direction of the forc

"In the inclined plane, the weight the power, if this be exerted in a dir parallel to the plane, as the perpend height of the plane is to it's length; power be exerted in a direction parall the baſe, as the height is to the baſe o plane.

"In the uſual compound pulleys, tackles, a power can ſupport a weight as times greater than itſelf as the numb times the rope by which it is ſuſpended round the pulleys."

F. "Very right; and theſe few prin will ſuffice, to give you a general idea c operation of many uſeful machines. I wil you now of a mechanical performance, w not to be compared with thoſe of Arch

des, was at leaſt bold, and executed with ſucceſs. It is not, however, the greateſt, or moſt celebrated, of modern times. Whoever ſees a high tower, which from age, or a defect in it's conſtruction, inclines to one ſide, ſo that the upper part threatens to tumble down, will ſay at the firſt ſight, it muſt be taken down, and rebuilt in a perpendicular poſition: the mechanical genius of an able architect alone could form the bold reſolution of reſtoring it to it's perpendicular as it ſtands. The ſoldier, it is true, holds up his head, and ſtands erect, at the word of command: but ſteeples are more ſtiffnecked. The greater power of mechanics, however, can force even ſteeples to obey.

" The circumſtance I am going to relate took place in Hamburgh ſome years ago. The ſteeple of St. Nicholas's church in that city is conſtructed of maſſy walls to a certain height. The upper part, in which there is a ring of bells, reſts on eight pillars. Theſe pillars perhaps were not ſufficiently firm at their baſe, to reſiſt the continued force of the ſtrong weſterly winds, ſo that they acquired an inclination to the eaſt, and this in ſuch a degree, as to deviate near a foot and

half from the perpendicular, which is no trifle. An architect, of the name of Sonnin, undertook to ſet the ſteeple upright again. Conſider now the difficulties he had to encounter. In the firſt place, the power required, to give ſuch a vaſt body the proper direction, could not be ſmall; but this was the leaſt difficulty: in bending a body of ſuch a kind by forcible means, was there not great reaſon to apprehend, that it would be thrown down? and then, by which moſt people would have been deterred, it was neceſſary to apply the force to the upper part of the ſteeple, to bend it to the weſtern ſide. Was not Sonnin here almoſt in the caſe of Archimedes, when he required a place, from which to move the Earth? Where, at ſuch a height, was he to find a firm ſtation for his machinery? The point, from which the power muſt act, was high in the air; and to erect a ſcaffold of ſuch a height, with ſtrength ſufficient for the purpoſe, would have required an expenſe much too great. Sonnin ſurmounted this difficulty by very ſimple means, ſuggeſted to his mind probably by the tackling of ſhips. The moſt eſſential parts of it I will exhibit to you in a figure; whether the ſteeple be like that of

t. Nicholas, or not, is little to the purpoſe.

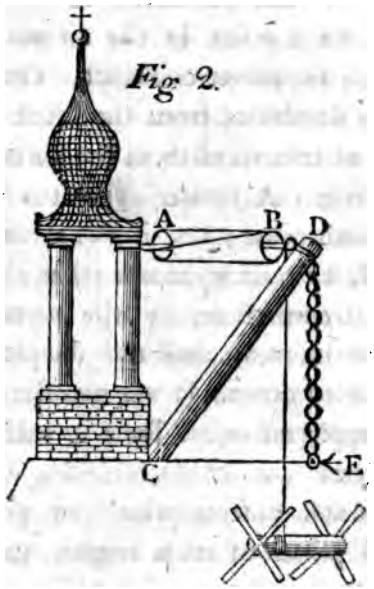


Fig. 2.

" A ſtrong beam, C D, was made to bear ainſt the baſe of one of the pillars at C, ere it was firmly ſupported, in an inclin- poſition. It's upper end, D, was connected th the top of the pillar by means of a tackle, B, and ſecured below by ſtrong iron chains, cending perpendicularly from D toward E. *ese chains held* the beam faſt, ſo that the

action of the tackle could not move it toward the pillar; consequently it must move the head of the pillar toward the beam. Thus the fixed point in the air was found, from which the power could act. The end of the tackle descended from the block B, and was fastened to a windlass in the lower part of the building. A similar apparatus was applied to each pillar; for, if the attempt had been made by pulling at one pillar alone, no doubt the connection of the parts would have been injured, and the steeple would have tumbled down. It was necessary, therefore, to apply an equal force to each of the eight pillars.

"We will now inquire how great the collective power of these engines may have been. Suppose we reckon eight men to each windlass, and consider each as applying a power of 20 pounds to his handspike. What was the amount of the whole power applied to each windlass?"

W. "Eight times 20, or 160 pounds."

F. "We will suppose, too, that from the part where the men grasped the handspikes to the axis was six times as long as the semidiameter of the windlass: how much *would* this increase the power?"

W. " Six times: ſo that it would be 6 times 160, or 960 pounds."

F. " If we farther ſuppoſe, that one of the blocks had three ſheaves, the other four, ſo that the rope paſſed ſeven times round them, what follows?"

W. " That the power was increaſed ſeven times; conſequently would be ſeven times 960, or 6720 pounds."

F. " Now, as there were eight ſuch machines, one for each pillar, how great would be the power of the whole apparatus?"

W. " Eight times 6720, or 53760 pounds."

F. " Such a vaſt power muſt certainly have been more than ſufficient; for it was not required, to lift the whole weight of the ſteeple, but only to move it about eighteen inches to one ſide. The weight to be moved was ſtill ſupported by the pillars; ſo that the machine had only to overcome it's lateral preſſure, and the friction and preſſure of the joints of the maſonry that were ſeparated."

CHAP. XIII.

OF THE FIGURES AND COLOURS OF CLOUDS.

No doubt, my young readers, you have often beheld with delight the beautiful appearances, that the clouds daily exhibit. I can remember well the pleaſure I felt, at an early age, in contemplating thoſe floating maſſes of infinitely diverſified ſhapes, colours, and motions. We are ſo much accuſtomed to the ſight, however, exhibited gratis too, that we pay it leſs attention than it deſerves. Clouds diſtinguiſhed by their ſplendour are perhaps looked at once, and admired; though their ſplendour is only borrowed, like that of many perſons of diſtinction: while thoſe, that appear in more ſober colours, paſs unnoticed, like one of the crowd; and we never deign to caſt an eye upon them, unleſs when we wiſh to know, whether we may take a walk without danger of a ſhower. *The clouds*, however, deſerve to be *conſidered as objects* of natural philoſophy, and

objects by no means deſtitute of amuſement.

We will firſt conſider their *figure*. This ſeems to be altogether caſual and irregular; yet, if we examine them more minutely, particularly thoſe in the higher regions, we ſhall find them more regular, than any one at the firſt view would ſuppoſe. They appear, in fact, to form parallel circles round the Earth, for the moſt part cut perpendicularly to it. Theſe parallel circles, indeed, are often thrown into diſorder by the winds; but, by a little attention, we may ſoon diſcern their original direction. Each parallel circle conſiſts of ſeveral clouds, as a file of ſoldiers conſiſts of ſeveral men. This form is apparently not owing to the wind, which frequently has a different direction; but to an undulating motion of the air, reſembling that of water, when a ſtone is thrown into it. We may obſerve, too, in theſe zones of clouds, that their progreſs is partly a parallel advance in a particular direction, partly a circular motion, as round a centre. In clouds that hang low this regularity *is not to be* obſerved; for, as they are *ſo near, we ſee* too ſmall a portion of them,

and in general their motion is more liable to be disturbed.

Single clouds, particularly in the lower regions of the atmosphere, exhibit the most diversified forms, baffling all description. Sometimes they rest on the horizon, towering over one another like snow-capped mountains; at others, they fly about, ragged and dispersed, in a thousand shapes, from which the imagination may figure out camels, or ouzels, with Hamlet, or all the monsters of romance. They chase each other, collect into one mass, or break into fragments, varying their outlines every moment. The lower edges next the Earth are commonly sharper, and less broken than the upper, which are ragged, like rocks, trees, or the like.

It is very entertaining, to observe the changes, which they are continually undergoing by imperceptible transitions. The air is seldom so completely still, that a cloud, on which you have fixed your observation, retains it's form unchanged many minutes. But changes in the forms of clouds are not *occasioned* by the motion of the air alone; *evaporation* and condensation have consider-

able effect in producing them. If you fix your eye attentively on any particular part of the upper edge of a cloud, you will often clearly perceive a vapour aſcending from it, as ſteam does from boiling water, with a whirling motion, which is perceptible even to the naked eye, though more ſo to a teleſcope of moderate power; and this vapour either ſeparates from it, preſerving a viſible form, or is gradually attenuated, and vaniſhes from the ſight. This pleaſing appearance I have obſerved particularly in the month of march, toward noon, when the previouſly cold cloud has become warmed by the Sun approaching the meridian, in places where the edge of the cloud, whitened by the Sun's light, has had a clear deep blue ſky for the back ground.

As parts of clouds, or even the whole, are ſometimes diſſipated by evaporation, and become inviſible; at other times they ariſe, and are enlarged, apparently out of nothing, of which we ſhall ſay more preſently.

But who can deſcribe the variety of their *colours*, with all their tints and ſhades! What *painter* can imitate them with earthy *pigments*, ſince he cannot dip his pencil in

ethereal light! To day, while a beneficial rain moiſtens the dry earth, the whole horizon is covered with one uniform duſky gray. Yeſterday, ſmall, white, fleecy clouds floated over the blue ſky, and, collecting in the weſt, announced to day's rain. Duſky, leaden, and brown thunderclouds hung below, threatening to fall in a body on the ground, as too heavy for air to ſupport. Again, at ſunſet, or at ſunriſe, what a beautiful diſplay of hues! Here float roſe-colour, purple, red, violet; there, nearer the horizon, are the blue mountains of clouds ſkirted with gold; and in the higher regions float ſtreaks of fire. The colour and ſplendour of the clouds evidently depend on their poſition with reſpect to the Sun and the obſerver's eye, and partly to the qualities of the vapour, of which they conſiſt; as they are all occaſioned by the various refraction or reflection of the rays of light.

CHAP. XIV.

OF THE MAGNITUDE AND WEIGHT OF CLOUDS.

CLOUDS evidently differ in ſize. There are ſmall clouds, that appear like flocks of wool; and large ones, that cover whole regions. Men have already attempted to meaſure clouds; and though little accuracy can be expected in ſuch an undertaking, we may, perhaps, form ſome concluſions reſpecting their bulk.

"How can clouds be meaſured?" perhaps my young readers will ſay.

In ſmall clouds, their magnitude may be inferred from the extent of the ſhadow they caſt on the ground. "But," you will ſay, "the ſhadow may be much larger than the cloud itſelf; for, if I hold a piece of paper between a candle and the wall, the ſhadow is much larger than the paper." That is true; and ſuch of you, as have learned the elements of geometry and optics, will know, *that the ſhadows* will be in proportion to

the ſquares of the diſtances; ſo that, for example, if the wall be three times as far from the candle as the paper is, the ſhadow will be nine times as large as the paper. But with regard to clouds, and in general when the light comes from the Sun, we may conſider the ſhadow as exactly equal in breadth to the body that occaſions it; for the Sun is at ſuch a diſtance from the object, that the difference between it's diſtance and that of the earth from the Sun cannot come into calculation. The thickneſs of a cloud can be obſerved beſt by aſcending high mountains. You may often ſee a cloud hanging on the ſide of a mountain over you. When you aſcend to a certain height, you will find yourſelf in a thick miſt, which is nothing more than the cloud: and, by continuing your progreſs through this miſt, you will find, at length, the clear ſky over your head, and the cloud beneath you. Thus you may eaſily calculate it's thickneſs.

We may form ſome conjecture alſo of the *weight* of a cloud of a given thickneſs. Suppoſe a cloud be 6000 feet long, 6000 feet broad, and 1000 feet thick; allowances *being made in* this calculation for the irregu-

larity of it's ſhape, ſo that what is left in one part may be compenſated in another: the cubical contents of this cloud will be 3600000000 feet. If we reckon the weight of a cubic foot of the air, in the region where this cloud is, to be one ounce; and we know, by the laws of hydroſtatics, which we had occaſion to inveſtigate in a preceding chapter, that it can remain ſtationary only where it's ſpecific gravity is exactly the ſame with that of the air, the ſpace of which it occupies; we ſhall find the weight of the cloud to be 225000000 pounds.

If we conſider the vapour, which properly conſtitutes the cloud, to be only a thouſandth part of the weight, which muſt be a very thin cloud however, we ſhall have for the weight of the actual ſubſtance of the cloud 225000 pounds. Muſchenbroek reckons the weight of the vapour at one-tenth, which would be a hundred times as much as we allowed in our inſtance.

CHAP. XV.

OF THE HEIGHT AND DISTANCE OF CLOUDS.

To aſcertain the height of clouds with tolerable accuracy, unleſs it be ſuch as we can reach by aſcending mountains, is ſcarcely practicable. The mere eye informs us, that they float at very different diſtances from the ſurface of the Earth. Heavy thunder clouds hang very low: even on moderately high mountains, you may ſometimes ſee the lightning beneath you. This beautiful natural phenomenon may be ſeen on the Brocken; and as this mountain is not much above 5000 feet in perpendicular height* it is evident, that thunder clouds may ap

* The Brocken in Saxony, like many other high mountains, has been reckoned by many much lower than it is. It's ſummit has been eſtimated by obſervations with the barometer at 3000 feet above the level of the town of Wernigerode; but Mr. Kiſs has found it, by trigonometrical meaſurement, to be 5300 feet;—a *trifling difference.*

proach within one or two thouſand feet of the ſurface of the Earth.

The light, white, fleecy clouds float at a very great height. Sauſſure, who aſcended the higheſt mountain we know in the old world, beheld them apparently as high above him on it's ſummit, as if he had been on the plain ground. Heavier clouds than theſe, too, muſt be found higher than the ſummits of the loftieſt mountains; for they let fall ſnow upon theſe ſummits. Bouguer obſerved clouds in South America at leaſt 800 fathoms, or 4800 feet, above the ſummit of Chimboraſſo, and this mountain riſes more than 19000 feet above the ſurface of the ſea.

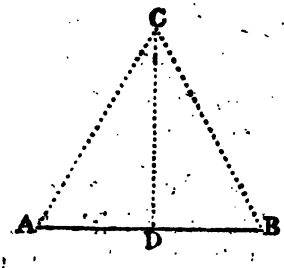
Perhaps ſome of my young readers will aſk, "How can we meaſure the height of clouds, which we cannot reach?" Such, however, as have ſtudied geometry, will know, that more difficult problems may be ſolved by it's aid. In theory, the matter in queſtion is eaſy enough; yet we cannot promiſe ourſelves much accuracy, when we attempt to put it into practice. This, however, is owing to no defect in the ſcience of *geometry: the difficulty* lies in determining

a certain point in a cloud, and obſerving it from two ſtations. As the whole figure of the cloud is ſo indeterminate, and it's outline ſo irregular; as a point, on which the eye may fix at one place, may be concealed by other parts of the cloud from a ſtation a thouſand yards off; and as the form of the cloud is continually changing; it is obvious, that two perſons cannot fix on a point to be obſerved with any great degree of certainty.

If they did ſucceed in fixing on a determinate point in the cloud, the two obſervers ſhould ſtation themſelves at ſome diſtance from each other, where the ſpace between them could eaſily be meaſured; obſerve the point fixed upon at the ſame inſtant; and take the angle, which a line drawn from this point to the obſerver's eye would make with the line drawn from one ſtation to the other. From the two angles thus taken, and the meaſure of the line between them, the perpendicular height of the point obſerved might be found. The inſtant when the obſervation is to be made from both ſtations muſt be ſettled; and each obſerver muſt be *provided*, for the purpoſe, with a watch

tells ſeconds, that they might make r obſervation at the ſame ſecond of ; or one may give the ſignal to the r by diſcharging a piſtol. The diſtance veen the two ſtations muſt not be too ll.

s we preſume ſome of our readers are ainted with trigonometry, we will add a iſe account of the manner of calculating height. Let C, in the triangle beneath, he point of the cloud obſerved, A and he obſervers' ſtations.

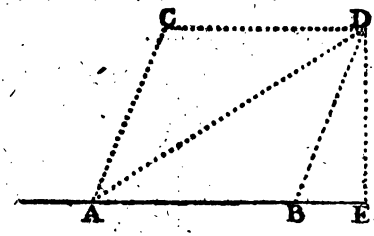


angles at A and B, and the length of ine between them, are known. Hence angle at C may be found, and then one he other ſides, for inſtance A C, by the *ortion, as the* ſine of C is to the ſine *ſo is A B* to A C. When you have *ound A C*, the ſide C D, in the right-

angular triangle A C D, or perpendic
ſought, may be calculated by the pro
tion, as the ſine of D is to the ſine of
ſo is A C to C D.

By this mode of meaſuring, Ric
found the height of clouds not al
25000 feet.

However, as this operation gives onl
approximation to the true height, per
the following mode might be advantage



Let C D be the diameter of a cl
A B, the diameter of it's ſhadow on
ground, which muſt be equal to C D, a
rays of the Sun, C A and D B, are par
The angle C A B is known, being tha
the ſun's height above the horizon: ſo i
angle A B D, as, with the former, it
make 180°. Now, while one perſon
meaſures the line A B, let another take
angle D A B. Thus, in the triangle A
we have the ſide A B, with the two a

angles, whence the third angle D, and the ſide B D, may be found. Now, in the rectangular triangle B D E, we have the ſide B D, the angle B, being that of the Sun's altitude, and the right angle E, known. Hence the ſide D E may be found. This proceeding, I confeſs, will be liable to the ſame difficulties in practice as the former; but it has this advantage, that the point D is to be obſerved only from one ſtation, A.

There is another mode of finding the height of a thundercloud, which happens to be over-head, namely, by obſerving the interval between the lightning and the thunder. From the aſtoniſhing velocity of light, the flaſh may be conſidered as ſeen the inſtant it takes place; but ſound requires a ſecond of time to travel the ſpace of 1000 or 1200 feet: if, therefore, five ſeconds elapſe between the time of our ſeeing the flaſh of lightning, and hearing the clap of thunder, we may infer, that the cloud is about 6000 feet diſtant. From the colour of clouds, too, we may form ſome eſtimation of their height, as Bernoulli obſerved, by noticing *the time* that elapſes between the *ſetting of the* Sun, and the vaniſhing of the

appearance, as they proceed toward the horizon in the oppoſite quarter.

" But," perhaps ſome of my more experienced young readers will ſay, " it is juſt the reverſe with the ſtars; for they ſeem farther apart at the horizon, than in the zenith." This is very true; but there is one eſſential difference between the two caſes: the diſtance of the ſtars is ſo great, that they are not perceptibly nearer to us in the zenith, than at the horizon; though they *appear* ſo, becauſe what we ſee over head ſeems to us nearer, than what we ſee at the ſame diſtance horizontally; a ſubject on which I ſhall enlarge more particularly on a future occaſion. Thus, the apparent diſtance of the ſtars is in fact the ſame at the horizon, as in the zenith, but we eſteem it greater, becauſe we imagine the ſtars to be more remote in that ſituation: with the clouds it is otherwiſe; they are far more remote from us at the horizon, than when over head, and conſequently their apparent diſtance is actually leſs.

Suppoſe we were to inquire how far a cloud, that we ſee at the horizon, muſt be from us, eſtimating it's perpendicular height above the *ſurface of the* Earth to be two miles; which

The motion of the higher clouds, too, as they are more remote, is apparently ſlower than that of the inferiour clouds, though in fact the ſame. On a windy day, when the Sun ſhines, and only ſingle clouds fly along, the velocity of the ſhadow on the ground will aſtoniſh you ſtill more, though this flies no ſwifter than the cloud itſelf.

The courſe taken by clouds in different regions of the air is not always the ſame. While the lower clouds fly ſwiftly, the higher may ſtand ſtill, or even move in an oppoſite direction: for at different heights in the atmoſphere different currents of air not unfrequently occur at the ſame time.

When clouds, coming from the horizon, appear partly to advance ſtraight toward us, partly to take a direction more to the right, and partly more to the left, this is an optical deception. As they proceed toward the eye of the obſerver in a parallel courſe, they muſt appear to diverge, according to the laws of optics, as their apparent diſtance from each other at the horizon muſt be leſs, than when they are over the obſerver's head: and, for the ſame reaſon, theſe very clouds, when they have paſſed the obſerver, muſt converge in

the ſquare of A B 15876; and the root of this is 126, the diſtance of the cloud from the obſerver in miles. Now a ſtrong wind is capable of bringing ſuch a cloud from the horizon to the zenith in three hours; for, if we reckon the wind to blow at the rate of 60 feet in a ſecond, it will move about 41 miles in an hour.

CHAP. XVII.

OF WHAT DO CLOUDS CONSIST?

THE ſubſtance of clouds is nothing but vapour. At a diſtance, indeed, a cloud appears to the eye a ſolid maſs; but when, aſcending a hill or mountain, we actually come into a cloud, we perceive nothing but a miſt around us, ſometimes ſo thick, that we can ſcarcely ſee ten yards before us, at other times extremely thin.

The ignorant alone ſuppoſe, that the dark blue or brown, or the beautiful red and yellow colours, exiſt in the clouds themſelves;

which is by no means the caſe. Theſe colours are entirely owing to the refraction and reflection of the ſunbeams. When we contemplate the beautiful diſplay of colours exhibited at the riſing or ſetting of the Sun, we might wiſh to be transformed into aerial beings, to recline on thoſe ſoft purple and roſy maſſes, and float with them high above the Earth: but he, who has once paſſed a day and a night in the clouds, as we did laſt year on the Brocken, will have no deſire to make them his bed. Our friends in Deſſau probably were enjoying the ſight of the roſy clouds fringed with gold in their weſtern horizon, while we, enveloped in the very clouds they admired, wiſhed them far away, becauſe they prevented us from beholding the ſetting Sun. Thus we are apt to be miſtaken in the value of things we contemplate at a diſtance, when we do not know what they really are, or neglect to conſider their real qualities, and confine our thoughts to theſe.

Of what, then, do clouds conſiſt? Of very fine *bladders* or *bubbles*, as Sauſſure's obſervations confirm; exactly as the ſteam aſcending from a *kettle* of boiling water, the blad-

ders of which are clearly enough perceptible to a magnifying glaſs.

But how are theſe bladders formed? On this the learned are not agreed; and it would afford you little amuſement, my young readers, were I to give you their opinions, with the ſeveral arguments adduced for and againſt them. Still you will be glad, probably, of one explanation at leaſt, capable of ſolving the phenomena, and we will therefore take the following*.

In the firſt place it is to be obſerved, that there is a very ſubtile fluid, which produces heat, or warmth, called the matter of heat.

This matter of heat is capable of combining with the particles of water, or any other fluid, ſo as to diſſolve it; and a fluid thus diſſolved in the matter of heat is called vapour.

* The theory here given is that of de Luc, which appears to be the moſt ſimple, eaſieſt to be comprehended, and to explain the greater part of the phenomena, at leaſt without violence. The theories of le Roi, Sauſſure, Hube, and others, are as hypothetical as de Luc's; and the ſimpleſt is the beſt for our purpoſe, though it may not be perfectly ſatisfactory. The reader *will remember*, however, that it is given as conjectural only, not as an explanation unqueſtionably juſt.

Vapour, as long as the ſolution remains perfect, is an inviſible elaſtic fluid. By an elaſtic fluid is meant a fluid, that has a conſtant tendency to expand itſelf, as much as the preſſure, to which it is expoſed, will allow. The great force of this expanſive power is evidently diſplayed in the ſteam engine, by means of which aſtoniſhing effects have been produced in mechanics.

But the matter of heat has a tendency to leave in part any warm body, and enter into a colder in contact with it, till both are equally warm. Thus when vapour comes into a colder place, a part of the ſolvent, or matter of heat, is abſtracted from it, and ſomething takes place ſimilar to what happens when the fluid in a ſolution of ſalt is diminiſhed. In ſuch a caſe, we know, the particles of the ſalt unite in a determinate figure, and form cryſtals: ſo, when vapour is cooled, the particles of water unite, and form bladders.

Yet why ſhould they aſſume this particular ſhape? This we are unable to explain; though it is not more ſtrange, that water on ſuch occaſions ſhould always form bladders, than that *every ſalt, when it* cryſtallizes, ſhould aſſume

it's appropriate figure, of the cauſe of which we are equally ignorant.

And what is contained in theſe bladders? That we cannot tell with any certainty. It muſt be a ſubtile elaſtic fluid, however, and of leſs ſpecific gravity than the air, as it enables the particles of water to float in it. Perhaps it may be ſtill the matter of heat, or the electric fluid.

Vapour may be condenſed by preſſure alſo, as well as by the abſtraction of the matter of heat, when the preſſure is carried to a certain degree. Thus we may compreſs aqueous vapour to a certain point, without the particles of water attracting each other, ſo as to become actual water: but if the preſſure be carried beyond this, the particles of water will be brought ſo near together, that their attractive power will overcome the expanſive power of the matter of heat, and the vapour will be in part decompoſed.

When vapour is condenſed into little bladders of this kind, it becomes viſible, and not before: and a collection of ſuch bladders, produced by the vapours aſcending into the atmoſphere, form what we call miſts and clouds. *When they* reſt on the Earth, ſo that we our

ſelves may walk in them, we call them miſts, or fogs: when they float in the air over our heads, we call them clouds.

CHAP. XVIII.

GREEN AND SHINING CLOUDS.

To finiſh the ſubject of clouds, we will add an account of ſome remarkable for their colour, form, or ſomething elſe ſingular in their appearance.

In ſome parts of the world a particular cloud occaſionally appears, to which the german mariners give the name of *hare*, on account of it's ſwiftneſs, and which indicates the ſudden approach of a heavy gale. A traveller informs us, that, being at ſea, he heard one of the crew call out, "here comes a hare," and immediately all hands were ſet at work, to take in the ſails, and prepare the ſhip for a ſtorm. As he neither found the wind blow, nor perceived any thing, that ſeemed to forebode a gale, he was ſurpriſed at the buſtle, and inquired into the reaſon of it. On this, a little

black cloud, low in the horizon, was pointed out to him, which ſeemed far off, and in which he could diſcern no tokens of danger. But this ſmall cloud enlarged viſibly, approached with aſtoniſhing ſwiftneſs, and ſcarcely were the ſails furled, before the cloud and the ſtorm arrived together.

The clouds, that hang on the peaks of many mountains, forebode wind and ſtorms; as on Mount Pilate in Switzerland, which derives it's name, *Mons Pileatus*, from it's head being capped with clouds.

At the riſing and ſetting of the Sun, it is uſual for the clouds to appear of various colours, but a green cloud is a very rare occurrence, though ſuch may ſometimes be ſeen. Fraſer once ſaw a green cloud at ſunſet in the torrid zone, and recorded it, on account of it's ſingularity. "Between the tropics," ſays Forſter, "the morning and evening Sun frequently paints the Heavens with brighter hues, and the mixture of colours is more ſtriking and conſpicuous." In the year 1774, on the ſecond of April, in the latitude of 9° 30′ ſouth, J. R. Forſter obſerved at ſunſet a very beautiful green cloud, at a little diſtance from it were clouds of an olive tint,

and even the ſky itſelf had a lively tinge of light green. The younger Forſter obſerves on this occaſion, that he had remarked the ſame phenomenon at Caſſel, in Germany, with all imaginable ſplendour of colour.

To theſe obſervations perhaps many of my readers can add ſome of their own. Thus in the middle of February laſt, after a clear froſty day, the ſky was uncommonly beautiful here at ſunſet and juſt after. Light violet clouds floated in the deep blue zenith; nearer the horizon were roſy red and flame-coloured clouds; and at the horizon in the ſouth weſt the ſilvery moon ſhone from a ſky gleaming with the moſt beautiful tranſparent green.

Inſtances of ſhining clouds too have been known. Thus abbé Rozier relates an obſervation of a cloud, that emitted light from being ſurcharged with electricity, at Beauſejour, near Beziers, on the 15th of Auguſt, 1781. The day had been very ſultry, and a thunderſtorm was expected. The ſky overhead had been loaded all day with denſe, white clouds, and the Sun ſet behind a vaſt body of ſuch clouds towering one over another. At ſeven o'clock in the evening the

atmoſphere grew ſtill more loaded with vapour; the great clouds ſunk lower in it; and the air became very thick and heavy, ſo as to render breathing leſs free. As night approached, the clouds heaped together more and more, and advanced nearer to the chain of mountains, that divides Lower Languedoc from eaſt to weſt. At a quarter after ſeven a faint gleaming was obſerved in the weſt, from which it might be inferred, that it was thundering at a diſtance in that quarter. The lightning ſoon increaſed, and the thunder began to be audible. At eight o'clock the wind blew from various quarters, driving the clouds in different directions, though the weſterly wind ſtill maintained the ſuperiority. The thunder grew more violent toward the mountains, and the whole ſky appeared in a blaze. Night now came, and it was impoſſible to obſerve the motion of the clouds any longer, as the vivid lightning ſo dazzled the eye, that the darkneſs appeared much greater probably than it was. The ſtorm drove haſtily from weſt to eaſt, and toward the mountains was tremendous. Five *minutes after* eight it was completely night. "*Juſt at this* moment," adds Rozier, "as

was obſerving the courſe and action of the lightning, I perceived, behind the brow of a hill, which bounds the proſpect from my houſe on one ſide, a luminous point. It was not the light of a diſtant torch, or of burning wood; for it's colour was too white, reſembling that of phoſphorus burning in the open air, or the electric light of an exhauſted glaſs tube. This luminous point ſpread more and more, and at length formed a ſtripe, appearing to the eye about three feet broad *. Over this ſtripe preſently appeared a ſecond of equal breadth, but only half ſo long, as it's extent was not above 30°. The ſpace between theſe two ſtripes, which was about the ſame breadth with them, remained perfectly dark. Theſe ſtripes had a horizontal direction, but their edges were not accurately defined, inequalities being clearly obſervable in them, as in thoſe large white clouds, which forebode a thunderſtorm. The edges too were not illumined with equal

* Theſe are Mr. Rozier's words; but the expreſſion is much too vague for a natural philoſopher, who ſhould eſtimate the magnitudes of appearances in the Heavens by the degrees and minutes of the angle they ſubtend *from the obſerver's eye.*

vividneſs, though the middle of the ſtripes diſplayed an equally diffuſed light. While theſe ſtripes moved on to the eaſt, the lightning followed flaſh after flaſh. At three different times a flaſh of lightning iſſued from the end of the lower ſtripe; but it was very remarkable, that no thunder was heard after theſe flaſhes; though the claps from the more diſtant clouds, which appeared over the ſtripes, were very tremendous. Every flaſh, that iſſued from the thundercloud itſelf, enabled me to ſee the whole country, ſo that I was more capable of forming a juſt idea of the two luminous ſtripes. Theſe ſtripes continued to be ſeen from five till ſeventeen minutes after eight, when a ſquall of wind from the ſouth altered the direction of the clouds, drove them nearer to the mountains, and carried the ſtorm away from Beziers.

"It may be preſumed, that theſe ſtripes were collections of electric vapour, rendered luminous by being much condenſed. The ſtrongeſt proof of this is, that the three flaſhes of lightning from one of them were double the diameter of thoſe, which iſſued *from* the thundercloud itſelf; though in eſti*mating this* diameter there may have been

ſome degree of optical deception from the nearneſs of the object. The ſtripes too were diſtinct from the cloud, becauſe the mountains could be ſeen behind them, and no thunder followed their lightning."

A ſomewhat ſimilar appearance was ſeen between Gotha and Erfort, on the 10th of January, 1782. About midnight, the ſky being clear, except a few ſtraggling clouds, ſeveral ſmall ſtreaks of fire aſcended from the ground at different times, about half a mile from the obſervers, which were at firſt taken for ſkyrockets. But as no ſound was heard, as they were not ſeen to burſt, and as it was perceived, that their courſe was from the ground to the clouds paſſing over, in which they diffuſed themſelves, even illumining them internally, they were concluded to be the effect of natural electricity.

abroad, that it was preſently loſt in a thin miſt.

Mr. Lichtenberg, who gives the above account, ſays, that he has ſince obſerved a ſimilar appearance, though not ſo ſtriking, in other thunderclouds. Sometimes, too, he has ſeen it reverſed; and, inſtead of a finer vapour being emitted, and forming a covering to the cloud, the thin white wrack, that has been floating over the thundercloud, has ſunk down, ſpread over it like a veil, and united with it.

That the vapour, in the inſtance above related, formed a ring round the cloud, aroſe from it's form. Being repelled by the cloud above and below, it could only diſtend itſelf laterally, till it got beyond the limits of the cloud, when it diffuſed itſelf upward and downward. If this appearance be compared with the electrical experiment, in which a ball of cotton is ſuſpended by a ſilken thread in a cylindrical veſſel of metal of a proper ſize, and the veſſel is alternately electrified, and deprived of it's electricity, perhaps we may reaſonably infer, that it is not very difficult to obtain information concerning the electrical ſtate of the higher regions of the air, and

f the clouds themſelves, by paying more ttention to the phenomena that occur in hem.

One afternoon, toward the end of March, a hunderſtorm aroſe from the weſt. When he horizon in this quarter had again leared up, and the ſtorm was gone by, I went nto the fields, to enjoy the agreeable proſpect, vhich both Earth and ſky commonly exhibit fter a thunderſtorm. Dark brown and leaden-oloured clouds ſtill floated ſlowly and heavily ver head toward the eaſt in groteſque figures. n the clear weſtern horizon the Sun, now ear it's ſetting, ſhone forth; and it's beams ainted one ſide of the clouds with a ſtrong ellow light, which formed a ſtriking contraſt vith the deep ſhades of the reſt. Among ll theſe ragged clouds of ſingular ſhape, which gradually paſſed along, driven by a moderate wind, one particularly attracted my notice. It had a ſtriking reſemblance to an immenſe canopy, or expanded umbrella; and the effect was heightened, by it's appearing, from the point whence I viewed it, to be ſpread directly over the town. The oblique poſition of the Sun gave the lights and ſhades ſo *ſtrongly, that* the figure could be diſ-

tinguiſhed to great advantage. The inferiour ſurface, which in moſt clouds is convex, was a conical cavity, the edges of which were ſharp and regular. The ſuperiour ſurface was more irregular, not unaptly reſembling a plume of yellow feathers on the huge cap. This fine ſpectacle continued in all it's ſplendour near five minutes, when the wind diſordered firſt the upper part of the cloud, then the under; preſently after which it began to rain, and the appearance gradually vaniſhed.

CHAP. XX.

SOMETHING MORE ON THE SUBJECT OF TOADS.

In the preceding volume it was ſeen, that the toad may juſtly be ranked among harmleſs animals; yet it is not improbable, that it may occaſionally prove injurious to creatures that devour it, as ſeems to have been the caſe in the following inſtances.

A healthy, lively dog, running about the *garden with his maſter in the ſummer of*

1794, found a toad of the common ſpecies, with warts on the back, and red eyes. The dog fell upon the toad, tore it to pieces, ſwallowed it, and almoſt immediately his lower jaw was convulſed, opening and ſhutting with a quick ſpaſmodic motion. At the ſame time he foamed at the mouth, and this continued near a quarter of an hour. From this period the dog became dull, and in the evening refuſed his food. The next day he would neither eat nor drink; and, his ſtate thus becoming ſuſpicious, he was chained up. On the third day it appeared, that this precaution was not unneceſſary, for evident ſymptoms of madneſs came on; and as theſe increaſed on the fourth day, he was killed.

In the dogdays of the following year, the ſame gentleman met with a ſimilar inſtance. Walking in the fields after a ſhower, the dog of a friend in company with him found a toad, and tore it to pieces, but did not ſwallow it. The lower jaw of the dog became immediately convulſed; white, frothy ſpittle flowed from his mouth; and this had ſcarcely ceaſed before he vomited up a conſiderable quantity of *white*, frothy ſlime, and appeared

perfectly dull and ſhy. Some medicines were adminiſtered to this dog, and he did not become mad: which, however, may have been prevented by his vomiting ſo ſoon after, and his not having ſwallowed the toad.

Poſſibly the toad may be noxious only at certain ſeaſons, or on being irritated by extreme pain; and under theſe circumſtances it's juices, at leaſt if ſwallowed, may be capable of producing that horrible diſorder, hydrophobia.

CHAP. XXI.

AN EXPERIMENT WITH A GLASS OF WATER.

WILLIAM had heard of turning a glaſs of water upſide down, without ſpilling any of it, and requeſted his father to ſhow him how it was to be done.

Accordingly Mr. Goodwin took a glaſs of water, put a piece of paper over it, and then inverted the glaſs, preſſing the paper cloſe to the mouth of the glaſs with his hand, and

holding it ſo, till the water remained ſtill in it's new poſition. He then took his hand cautiouſly away; the paper remained fixed to the glaſs, and the water in it.

"Ah, the paper ——" William began: but he preſently reflected, that the paper was not a fixed covering, and that it was as ſingular for the paper to adhere to the glaſs, as for the water to remain in it.

Father. "Well, William, how is it? The whole weight of the water preſſes on the paper, and yet neither of them falls to the ground."

William. "I do not know."

F. "There is nothing above, that holds the water; for the coheſion of the water, and it's adheſion to the glaſs, are not ſufficient, to keep ſuch a weight ſuſpended: ſomething beneath, therefore, muſt preſs againſt the paper; and this can be nothing but the air, for you ſee there is nothing elſe under it. Thus it muſt be the *preſſure of the air*, that keeps the water ſuſpended in the glaſs."

"The preſſure of the air!"—ſaid William, reflecting on it, for it did not appear to him clear, how any thing could preſs from below upward.

F. "I muſt inſtruct you a little more in the properties of the air, otherwiſe you will not be able to underſtand the phenomenon.

"The air is a thin ſubſtance, that ſurrounds the whole Earth. We cannot ſee it indeed, but it's effects are viſible. The leaves and branches of trees are moved, without any thing being ſeen to touch them: ſo the vanes of a windmill are driven round, and a ſhip with ſpread ſails is impelled along. The wind, that effects all this, is nothing but the inviſible ſubſtance, which we term air, ſet in motion. If you move a fan, a piece of paper, or the like, backward and forward, you feel, that ſomething reſiſts it: you feel the impulſe of this inviſible ſubſtance againſt your face, againſt your hand: you hear a whiſtling or ruſtling noiſe, when you move a ſtick or a twig quickly up and down in it. I need not mention more of theſe known experiments, which will convince you of the exiſtence of a ſubſtance, that the eye cannot diſcern, even if aſſiſted by the beſt magnifying glaſſes. This ſubſtance, which ſurrounds us on all ſides, is diſtinguiſhed from other aëriform *ſubſtances* by the name of *atmoſpherical air*. *The firſt of* it's qualities, which I ſhall notice

is *fluidity*. You know, I believe, in what this conſiſts, or how fluids differ from ſolids."

W. "In ſolids all the particles cohere ſo ſtrongly together, that the body has a determinate figure; and this figure cannot be changed, or parts ſeparated from it, without force. In fluids the coheſion of their particles is ſo ſlight, that theſe particles eaſily move about among each other, and take the form of any veſſel, into which they are put."

F. "This quality the air poſſeſſes in common with other fluids, with water for example. It's particles may be ſeparated with eaſe, for it is done at every motion we make: yet the reſiſtance of the air is very perceptible, when a body is moved in it ſwiftly, or has a great ſurface perpendicular to the line of motion. Many of my readers, no doubt, have heard of a ſtriking inſtance of this, in the deſcent of Mr. Arnold from a great height in the air by means of a parachute. This was a machine in the ſhape of the head of an umbrella, but very large. From it a car was ſuſpended, in which Mr. Arnold ſat. Being faſtened *under the* car of an air-balloon, it *was carried up with it to* a conſiderable height

On this he took a glaſs tube, about the ſize of a large quill, thirty inches long, and cloſe at one end. Holding the cloſed end downward, he filled the tube with quickſilver, put his finger over the open end, inverted the tube, held it over a cup with the open end downward, and withdrew his finger. Some of the quickſilver now ran out, and left an empty ſpace or vacuum, at the upper end: but this was not more than two inches in length, the other twenty eight inches remaining full of quickſilver.

"Do you know the purpoſe of this experiment?" ſaid he to his ſon.

W. "We wanted to know the preſſure of the air; and by this we ſee, it is ſufficient to ſupport a column of quickſilver 28 inches high."

F. "As quickſilver is fourteen times as heavy as water, how high a column of water would the air ſupport?"

W. "The column of water would be fourteen times as high, that is, 14 times 28 inches, which make 392 inches, or 32 feet eight inches."

F. "Now you may imagine, that, as I *told you* before, you could not ſupport the

column of air, that preſſes upon your hand, if the ſurrounding air were removed."

W. "Yes: but there are two things, that are not very clear to me."

F. "What are they?"

W. "Why is it, that, in the experiment with the glaſs, the water would not remain in it, when the paper was taken away? The preſſure of the air was not removed."

F. "The reaſon is, the lower ſurface of the water does not remain perfectly at reſt in a horizontal poſition, ſo that the preſſure is not every where equal and uniform, and in conſequence the air, being the lighter fluid, aſcends, while the water deſcends. In a ſlender tube like this, when inverted, the coheſion between the particles of water at ſo ſmall an aperture would be ſufficient, to preſerve a ſmooth ſurface, without any paper, ſo that the air beneath would preſs uniformly againſt it, and ſupport it."

W. "I have ſtill another difficulty. We are here in a room, which has a ceiling over head. The air over this ceiling cannot preſs upon any thing in the room: the preſſure of the air *out of doors*, therefore, ought to be

much greater than within; yet I find no difference."

F. "You muſt conſider, the air is fluid and elaſtic. The air without doors is preſſed upon by the air above it: but as fluids preſs equally every way, the preſſure on the air without is communicated to the air within, through the door, windows, and chimney, ſo that both are equally compreſſed, and conſequently the preſſure they exert upon objects is equal.

"Let us now calculate with how many pounds weight the air preſſes upon this table, for inſtance. How muſt we ſet about it?"

W. "We muſt firſt meaſure the ſurface of the table, and then calculate the weight of a column of water of the ſame dimenſions and thirty two feet eight inches high."

William meaſured the table, and found it to be three feet long, and two feet broad. The ſurface therefore was ſix ſquare feet. Multiplying the height of the column by this gave a product of 196 cubic feet; and this multiplied by 62 pounds and half, the weight of a cubic foot of water, gave 12250 pounds.

F. "Hence you may infer the greatneſs of the force, with which our bodies are con-

tinually preſſed on all ſides. Had they not equally elaſtic air within them, which counterbalances the enormous weight, we muſt certainly be cruſhed to death. On the contrary, were the preſſure of the circumambient air removed, the air within us would burſt our bodies by it's expanſion."

CHAP. XXIII.

OF THE BAROMETER.

WILLIAM had frequently ſeen his father looking at a barometer, and raiſing or lowering an index at the upper end, but he did not underſtand the uſe of the inſtrument, or what was in fact to be obſerved in it. The experiment with the glaſs tube in the laſt chapter now led him to conjecture, that it muſt relate to the preſſure of the air, and this he mentioned to his father.

"You have gueſſed right," ſaid Mr. Goodwin: "here, examine the inſtrument a little more cloſely. You perceive, it is nothing *more than a glaſs tube*, cloſe at top, bent

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round and open below, and nearly full of quickſilver. This quickſilver is ſupported in the tube by the preſſure of the air, which acts only on the ſurface of the quickſilver in the ſhort open leg, as the ſpace above the quickſilver in the cloſed end of the tube is a perfect vacuum: for, when the barometer was made, it was completely filled with quickſilver, which ſunk down by it's own weight, when the tube was inverted, as you ſaw yeſterday; ſo that no air could have gotten into this ſpace, unleſs it had been admitted purpoſely. In a good barometer, ſhaking the tube will produce an audible ſound from the quickſilver at the top; but this will not occur, if there be air over it.

"The purpoſe of this inſtrument you will underſtand yourſelf: it ſerves to meaſure the preſſure of the air. For inſtance: the quickſilver now ſtands at the height of 28 inches in the tube; what does this prove?"

W. "That the preſſure of the air on the ſurface is equal to the preſſure of a column of quickſilver 28 inches high."

F. "But, when the quickſilver riſes in the tube?"

W. "The preſſure of the air muſt be great-

er; and, on the contrary, when it falls, the preſſure muſt be leſs. This is clear: but why is the lower end round like a ball?"

F. "The reaſon is this. A mere ſtraight tube, open at the end toward the ground, would not anſwer the purpoſe: for, not to mention the eaſe with which ſome of the quickſilver would be thrown out whenever it was moved, ſome muſt be loſt when the quickſilver deſcended from the diminution of the preſſure, and the remainder would not be ſufficient to balance the increaſed preſſure of the air. The lower end, therefore, muſt either be placed in a veſſel to hold the quickſilver, or bent round, which, you muſt be aware, is the moſt commodious.

"Still there is ſomething more to be conſidered. When the quickſilver falls in the longer leg, it riſes in the ſhorter: and the contrary. Now, if the ſhorter leg be wide compared with the longer, it will riſe in it but a little way, while it falls conſiderably in the other. The height of the column of quickſilver, ſupported by the air, muſt be reckoned from a horizontal line drawn level with the ſurface of *the quickſilver* in the ſhorter leg; *for all the quickſilver* below this line in the

longer leg is counterpoiſed according to the laws of hydroſtatics by the quickſilver in the ſhorter. Now, if the height of the quickſilver in the ſhorter leg be very little altered, which is the caſe when it is of conſiderable width, as I obſerved before, no great errour ariſes from the meaſuring the height of the columñ ſupported by the preſſure of the air in all caſes from a fixed point. This is the reaſon why the common barometer has a ball at the lower end.

"Still it would be more accurate, to leave the barometer tube of equal ſize throughout, and obſerve the riſe and fall in both legs. In this caſe, if the quickſilver fell one line in the longer leg, it muſt riſe one line in the ſhorter, and conſequently the column of quickſilver ſupported by the air would be two lines ſhorter than before."

W. "Why, then, do people call this inſtrument a weather glaſs?"

F. "It has ſome claim to the name, becauſe fine and ſettled weather generally follows the riſing of the quickſilver; and when it falls, variable, ſtormy, or wet weather commonly enſues. The reaſon of this, however, I can-

not well explain to you; indeed we do not know the cauſes of it with any certainty.

"What the barometer properly ſhows is an increaſe of the elaſticity of the air when it riſes, and a diminution of the elaſticity of the air when it falls. Now, aqueous vapour, while it exiſts in an undecompoſed ſtate, is very elaſtic, and perfectly tranſparent: whence it increaſes the elaſticity of the air, and leaves it clear. The riſe of the barometer, therefore, may be conſidered as an indication, that probably the elaſticity of the air is increaſed by aqueous vapour in a ſtate of perfect ſolution, and that the weather will be on this account fine. On the other hand, if the quickſilver fall, it may be preſumed, that the vapour, before perfectly mixed with the air, is decompoſed, by which the elaſticity of the air is diminiſhed; and that rain, or changeable weather, may in conſequence be expected. We muſt not flatter ourſelves, however, as I ſaid before, that this is a perfect explanation of the phenomena."

CHAP. XXIV.

THE THERMOMETER.

W. "WHAT is the uſe of this little glaſs tube by the ſide of the greater?"

F. "The little tube is a *thermometer*, that is, an inſtrument for meaſuring the warmth of the air, or any thing elſe that ſurrounds it.

"It is a well known fact, which you yourſelf have often experienced, that heat enlarges bodies, and cold diminiſhes them. An iron ball, which will juſt paſs through a hole when cold, will not go into it when heated. An iron rod is perceptibly longer when hot, than it is when cold. This effect of heat is the principle, on which the thermometer is conſtructed. The ball, and part of the tube, are filled with quickſilver, or with pure ſpirit of wine tinged red: if either of theſe fluids be expoſed to heat, it expands, and conſequently riſes higher in the tube; when it is *cooled*, it ſinks. Spirit of wine, however, is

much inferiour to quickſilver for the purpoſe, and now ſeldom uſed.

" By the ſide of the tube is a ſcale, and on it is marked the height, to which the fluid riſes at different degrees of heat. Two principal points in it are firſt aſcertained: that at which water freezes, and that at which water boils. The interval between theſe two points is divided into a certain number of equal parts, or degrees. Natural philoſophers, however, have differed in their diviſions, whence we have thermometers with different ſcales.

" The principal are Fahrenheit's, which is uſed in England; Reaumur's, as it is called, heretofore uſed in France; Celſius's, or the Swediſh; and de l'Iſle's, or the Ruſſian. The diſtance between the point at which water freezes, and that at which it boils, is divided into 180 degrees in Fahrenheit's ſcale, 80 in Reaumur's, 100 in Celſius's, and 150 in de l'Iſle's. Reaumur and Celſius began their ſcale from the freezing point, expreſſing this by 0: Fahrenheit began his 32° below the freezing point, making that of boiling water 212°: and de l'Iſle began his at the boiling point, from which he reckoned the degrees downwards. *It is to be obſerved*, that the thermometer

invented by Reaumur was made with ſpirit of wine, and it's ſcale does not agree exactly, though it does nominally, with that which now goes by his name, though in fact invented by Mr. de Luc. The thermometer commonly called Reaumur's, therefore, ought in ſtrict propriety to be called de Luc's. This and Fahrenheit's were the moſt common, but now that with the decimal division, or Celſius's, is generally used in France.

"Every thermometer muſt have it's ſcale adjuſted to itſelf, for the quickſilver will riſe or fall through a greater or leſs ſpace, with the ſame degree of heat, according to the ſize of the ball, and the diameter of the tube."

W. "Is not the ball unneceſſary? for the quickſilver, or ſpirit, would expand with heat, and contract with cold, if there were only a tube partly filled with it."

F. "We might do without the ball, it is true; but it would be very inconvenient: for, if we would mark ſlight changes in temperature, we muſt have the tube very long in this caſe. Thus, for example, ſuppoſe a change in temperature, that ſhould expand *the quickſilver* a thouſandth part of it's ſolid *contents*: if the column of quickſilver were *ten inches*, or 100 lines, long, and the tube

a quarter of a line ſquare, the ſolid contents of the column of quickſilver would be 25 cubic lines, and the expanſion would be $\frac{35}{1000}$, or $\frac{1}{40}$, of a cubic line. But, the tube being $\frac{1}{4}$ of a line ſquare, the quickſilver would riſe only $\frac{1}{10}$ of a line, which would be a length not eaſily obſerved.

"Now, if to a tube of this ſize we add a ball containing half a cubic inch, or 500 cubic lines, we ſhall have a much larger body of quickſilver, with the ſame length of tube: for, theſe 500 cubic lines of quickſilver being added to the 25 in the tube, we ſhall have in the whole 525 cubic lines, the expanſion of which, with an equal degree of heat, will be $\frac{525}{1000}$ of a cubic line; and conſequently the quickſilver muſt riſe two lines and $\frac{1}{2}$ in the tube, to fill this ſpace."

William did not immediately underſtand how this was found: his father, therefore, explained it to him.

F. "As the ſolid contents of the quickſilver are 525 cubic lines, an increaſe of a thouſandth part muſt be $\frac{525}{1000}$ of a cubic line. If the tranſverſe ſection of the column were exactly a ſquare line, the addition of $\frac{525}{1000}$ *of a line to it's* height would give $\frac{525}{1000}$

of a cubic line: but, as it's tranſverſe ſection is only $\frac{1}{4}$ of a line, it requires of courſe four times as much additional height. If, therefore, we multiply $\frac{525}{1000}$ by 4, we ſhall have $\frac{2100}{1000}$ $=\frac{21}{10}=2\frac{1}{10}$.

"This is a length, which may be obſerved with eaſe: and if we have the thermometer with a ball of tolerable ſize proportioned to it's tube, we may conveniently obſerve with it all degrees of heat, not exceeding that of boiling water, though the tube do not exceed a foot in length. To meaſure higher degrees of heat, that at which quickſilver boils, for example, which is 600 of Fahrenheit, we muſt have longer tubes it is true: but from what has been ſaid it is clear, that a tube without a ball, capable of ſhowing tolerably ſmall changes of temperature, muſt be of ſuch a length, as to be extremely inconvenient."

CHAP. XXV.

MAGICAL FOUNTAINS, MAGICAL CUPS, &c.

As William went into his father's ſtudy the next day, he ſaw the table covered with various inſtruments, with which he was unacquainted.

"I believe," ſaid his father, "I can ſhow you ſome very amuſing experiments, effected by means of the preſſure of the air."

William was all attention.

F. "This (fig. 4.) is called a taſter, and is uſed for taking wine or any other liquor out of a caſk. Being put into the bunghole, the liquor flows into it, till it is on a level with the reſt: the hole at the top is then ſtopped by putting the thumb over it, and the taſter being lifted up, the preſſure of the air againſt the ſmall aperture at bottom prevents the liquor from running out. You may then ſuffer it to run into a glaſs at pleaſure, *by removing* your thumb, ſo as to *allow the air to* preſs upon the upper ſurface

as well as the lower; and may ſtop the iſſue of the liquor when you think proper, by replacing your thumb on the upper orifice.

" This (fig. 5) is called a *magical fountain*, or *fountain at command*. It is thus conſtructed. The pillar (*a*), on which the upper veſſel (B) reſts, is hollow, and reaches above the ſurface of the water in the reſervoir (B), which is covered cloſe. Near the bottom, which is in the baſin (C), there is a hole on one ſide; and as long as the external air can have acceſs to this hole, it riſes through the pillar into the reſervoir (B), the water in which conſequently flows out through the two ſmall pipes (D, E) into the baſin below. The baſin is thus gradually filled, till the water gets above the opening in the bottom of the pillar, and ſhuts out the air; on which the water ceaſes to flow. In the bottom of the baſin (C) however there is a hole, leſs than thoſe in the upper reſervoir (D, E), ſo that it could not diſcharge the water from the baſin ſo faſt as it ran into it, but through which the baſin now empties itſelf into the lower reſervoir (F). When the water thus *gets below the* opening at the bottom of the *pillar, the air* has again acceſs to the upper

reſervoir, and the two fountains begin to flow afreſh. Thus they go on alternately flowing and ſtopping; and, if you attend to the hole in the pillar, you will know when it will flow, when not, and conſequently may appear to order it to ſtop, or to flow. If the hole at the bottom of the pillar, inſtead of opening into the baſin, were connected with the outſide of it by means of a tube, as in ſome of the contrivances to be mentioned preſently, the orifice of which could be ſtopped at pleaſure, you might really cauſe the fountains to flow or ceaſe at will.

" This (fig. 6) is a magical caſk. Turn the cock: you find nothing runs out. Now ſhut the cock, take out the bung, and with this funnel pour water into the bunghole."

William did ſo.

F. " Take this glaſs, hold it under the cock, and turn the cock once more."

To William's great aſtoniſhment, he found his glaſs now filled with wine.

F. " Can you account for this?"

W. " No."

F. " I will explain it to you. The caſk is divided within by a partition, which is *cloſe at the bottom* and ſides, but admits a

communication between the two parts near the top. The cock opens into one part; the bung into the other. I had previouſly put wine into that part, where the cock is; but the aperture of the cock being ſmall, and the bung being ſo tight, as to exclude the external air, it would not run out, when the cock was turned. The water, being poured into the other part, remained ſeparate from the wine; but it compreſſed the air over the wine, ſo as to cauſe the wine to run out, when you turned the cock again.

"This compreſſed jet d'eau (fig. 7.) is commonly called a *Heron's ball* in Germany. The glaſs ball being about half filled with water, you blow air in through the tube, which reaches almoſt to the bottom. The air, thus compreſſed over the water, ſtrives to expand itſelf as ſoon as the force is removed, and thus drives the water out of the tube, the aperture of which being very ſmall, it riſes in a jet. As the air within dilates, the water is driven out with leſs and leſs force, till the denſity of the air within is reduced to an equality with the denſity of *the external* air. By blowing air in again in *the ſame* manner, you may make the foun

tain play afreſh, till the water is too low in the ball. To fill the ball, you muſt proceed in an oppoſite manner; ſucking the air out, and preventing the admiſſion of freſh air by turning the cock in the neck, till the end is plunged into a veſſel of water, when, the cock being turned again, the preſſure of the external air on the ſurface of the water will force it into the tube. If the ball and tube were made of copper, and ſtrong, and a good ſyringe fitted to it ſo as to be air-tight, the air in it might be condenſed to a great degree, by forcing it in with the ſyringe, or by forcing in the water upon the air with this inſtrument."

A ſimilar fountain to this William contrived to make himſelf, by fixing a ſlender ſtem of a tobacco-pipe in a ſtrong phial, ſo as to be air-tight, with ſealing wax.

F. "In the circulating or Heron's fountain (fig. 8.) the water is driven out in the ſame way as in the magical caſk. Two of the pillars, that ſupport the upper reſervoir, are hollow. One (D) reaches from the bottom of the baſin (A) into the lower reſervoir (C); the other (E), from the lower re-

ſervoir (C) to the upper (B), in wh
opens near the top, ſo that it's apert
above the ſurface of the water in the
reſervoir. In the centre of this upp
ſervoir is a tube (F), reaching almoſt
bottom, and opening with a very ſmall
at top, through which the jet riſes. A
as the baſin (A) is empty, there is n
pearance of any jet; but the baſin
filled with water, it deſcends throug
hollow pillar (D) into the lower reſervoi
drives the air out of this reſervoir th
the other hollow pillar (E) into the u
where it preſſes on the ſurface of the
and forces it out through the tube (F
jet. The water of the jet, falling bacl
the baſin, deſcends from it into the
reſervoir; and conſequently the fou
continues playing, till the upper reſ
is emptied."

CHAP. XXVI.

SIPHONS, AND TANTALUS'S CUP.

F. "THIS curved tube (fig. 9.) is a *ſiphon*. Fill it with water, and then put the ſhorter leg into this tumbler."

William had no ſooner done it, but the water began to run out of the longer leg; and, to his aſtoniſhment, continued, till the tumbler was nearly emptied of the water previouſly contained in it.

F. "What, do you ſuppoſe, is the reaſon of this?"

W. "It appears as if the water in the outer leg of the ſiphon, as it ran out, drew that in the other leg, and in the glaſs, after it."

F. "You have juſt the ſame idea of it, as many others before you have had, ſome of whom might have been preſumed capable of judging better. The cohefion of water is far too weak, to produce ſuch an effect; which would be, as an intelligent man once *wittily obſerved*, the ſame thing as making

a rope of water. There muſt be ſome other cauſe, therefore: and this is nothing but the preſſure of the air, and the unequal reſiſtance of the two columns of water, which, it is to be obſerved, muſt be unequal, from the inequality in the length of the two legs. The preſſure of the air againſt the water in each leg is to be conſidered as the ſame; ſince the apertures of both are equal, and the little depth to which the ſhorter is immerſed in water does not make any perceptible difference. But the height of the columns of water in the two legs not being the ſame, they do not reſiſt the preſſure of the air equally, and conſequently are not in equilibrio.

"Suppoſe the length of the longer leg to be 60 lines, that of the ſhorter 55. If one leg only were filled with water, the air would preſs equally on each end of the column, and the water would run out by it's own weight, as from a tube open at both ends; but, when both legs are full, the air is prevented from preſſing upon the top of either column, by the weight of the water in the other. Hence, as the preſſure of the air upon the top of the ſhorter column

reſiſted by a column of 60 lines of water, while that upon the top of the longer column is reſiſted by a column of water of 55 lines only; the water in the longer leg muſt be preſſed downward with a force equal to that of a column of water of 5 lines, in addition to that which counterbalances the preſſure upward. Conſequently the water will begin to flow out of the longer leg; and, as it flows, the water muſt be impelled up the ſhorter leg by the preſſure of the external air, which then will have nothing to overcome but the weight of the water in that leg. Thus the water will continue to flow out of the longer leg, and up the ſhorter; till, the ſurface of the water in the veſſel being reduced below the opening of the ſhorter leg, the air enters into it, and empties the ſiphon."

On the table ſtood a pewter goblet with a cover (fig. 10). William had been deſired to fill it nearly with water, before his attention was called to the ſiphon, and he had done ſo. On uncovering the veſſel, the water ſtill remained in it, and his father deſired him to fill it now to the brim. This was ſcarcely done, when he perceived the

quantity diminiſh; and it continued decreaſing, till the goblet was empty; the water having entirely vaniſhed, without there being the leaſt appearance of it on the table, or any where elſe. The goblet being filled again, remained full. Mr. Goodwin then poured out the water: a third time it was filled; and it emptied itſelf as before.

F. "A ſimilar exhibition by profeſſed jugglers has often excited no ſmall degree of ſurpriſe and wonder in a numerous company; but you, I preſume, can gueſs at the principle on which it is founded. You will readily ſuppoſe, that there is a ſiphon concealed in the goblet. The ſides of it, in fact, are double; and there is a ſiphon between them, the ſhorter leg of which opens at the bottom of the part into which the water is poured, the longer into the foot, which is hollow, and equal in capacity to the cup part. In the upper part of the ſtem are holes, that the air may have free iſſue from the bottom. As the ſiphon reaches nearly to the top of the veſſel, and is at firſt empty, the water, when poured in, riſes as high in *it, as in the* veſſel itſelf, but no higher. *As long, therefore,* as the ſurface of the water is

elow the top of the ſiphon, it remains in
ıe veſſel: but as ſoon as the veſſel is filled
igher than the top of the ſiphon, water
aſſes over into the longer leg, the ſiphon
egins to act, and thus the water is gradu-
ly emptied into the hollow foot. The foot
eing filled, the ſiphon cannot act, when
ıe veſſel is filled again: but the foot being
mptied through the holes in the upper part,
hen the water is poured out, the ſiphon is
gain capable of acting as before. This cup
as been made with a figure of a man in the
ntre, and a ſiphon concealed in the figure
f ſuch a height, that, juſt before the water
aches the mouth of the man, the ſiphon
ts, and empties the veſſel. Hence it has
rived the name of Tantalus's cup."

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CHAP. XXVII.

THE OBSEQUIOUS DIVER.

Among the reſt of the articles on the *ble William* obſerved a glaſs jar, nearly

filled with water, containing the figure of a man in enamel floating in it, and the mouth covered with a piece of bladder tied on it. His father, placing his fingers over the mouth of the glaſs, commanded the figure to deſcend, to riſe again, quickly or ſlowly, and was punctually obeyed; the little figure turning round ſometimes as ſwiftly too, as if he had been impelled by the vortices of the inventor of the experiment, des Cartes.

"That is very pretty!" exclaimed William.

F. "Are you not ready with our old queſtion too:—what is the reaſon of this?"

W. "It muſt be done by your fingers, which you hold over the glaſs; for there is nothing elſe to act upon the figure: but I cannot tell how, and ſhould be glad to know."

F. "I will inform you. The figure is hollow, of nearly the ſame ſpecific gravity with water, and has a ſmall hole in one foot.

"When I preſs down the bladder with my finger, the air, being compreſſed, forces a little water into the figure. This renders it *heavier* than the water, and conſequently it *ſinks*. The preſſure being taken off, by w

moving my finger, the air, which had been compreſſed within the figure by the entrance of the water, by it's elaſticity forces the water out again, and the figure aſcends to the ſurface. If I preſs lightly on the bladder, but little water is forced in, and the figure does not ſink to the bottom. If I make the preſſure gradually, it ſinks ſlowly: if ſuddenly, it ſinks quickly. It is the ſame with it's riſing. The circular motion it has is owing to the hole being on one ſide: for, when the finger is ſuddenly raiſed, the water iſſuing out quickly is reſiſted by the water in the veſſel, which does not immediately yield to the impulſe; and thus it's reaction, being exerted on one foot, turns the figure round. The celebrated Wolf, indeed, explains this rotatory motion in a different manner: but he only ſhows, that he did not underſtand it. Which I mention, as the inſtance of Buffon, on occaſion of the animalcula of infuſion, to remind you, that you ought to examine every thing for yourſelf, and not be led away by the authority of a great name."

William now tried the experiment himſelf; and was not a little pleaſed, to find how well

he ſucceeded. When he had amuſed himſelf with it as long as he thought proper, he placed the jar in the window, which faced the ſouth-weſt. The next morning he invited one of his play-fellows, to ſee him perform the experiment, by which he had been ſo much entertained: when, to his great diſappointment, he found his inanimate diver lying at the bottom of the glaſs, from which he would no longer riſe at his command. He preſſed upon the bladder with his finger, and removed the preſſure repeatedly, to no purpoſe. He ſhook the jar carefully, ſo as not to break the brittle puppet: but in vain. That water had gotten into the figure, and rendered it too heavy, William readily conjectured; yet he could not account for it. The jar had ſtood unmoved: both it and the figure were uninjured: the bladder was tied on as tight as ever: and, indeed, no one had been in the room. He went to his father, to know what was to be done.

"There is no difficulty in remedying it," ſaid his father, "we have only to ſuck the water out of the figure: but how did it get in?"

W. "That I came to aſk you: I have not *touched* the glaſs ſince yeſterday."

F. "But you let it ſtand expoſed to the Sun, and that was the cauſe. The heat of the Sun expanded the air within the figure, and conſequently forced ſome of it out, which immediately roſe to the ſurface of the water. As ſoon as night came on, and it grew cool, the air within the figure was no longer rarefied, but returned to it's former dimenſions; and of courſe water ruſhed in, to fill the ſpace, which had been occupied by the air, that was expelled. Accordingly the figure was rendered heavier than water, ſunk to the bottom, and will not riſe, till the water is extracted."

CHAP. XXVIII.

SOME ENTERTAINING EXPERIMENTS.

How to place a glaſs of water on the table, ſo that a perſon cannot take it up without ſpilling it.

PUT a piece of paper over the mouth of the glaſs; turn it upſide down, as in chapter

XXI; and then place it in this poſition on the table. When you have done this, holding the glaſs carefully with one hand, draw away the paper cautiouſly from under it with the other, and no one can take the glaſs up, without ſpilling the water, unleſs he have the art to reverſe the proceſs. This may be done, if you take another piece of dry, ſmooth paper, tolerably ſtiff, but not thick, and ſlide it carefully underneath the glaſs; you may then lift the glaſs off the table again.

On the former occaſion, in chap. XXI, the general principle only was aſſigned, the preſſure of the air from below upward: for ſuch of our readers, however, as reflect a little deeper on things, we will go a little farther into the ſubject.

"It is true," ſuch a one may ſay, "the air preſſes from beneath upward: but the ſpace above the water, in the inverted glaſs, is not a vacuum, as in the torricellian tube*;

* The barometer is ſo called from it's inventor Torricelli. A vacuum, produced in the manner in which that over the quickſilver in the barometer is made, is for the ſame reaſon called a torricellian vacuum.

r, when the glaſs is inverted, the air, hich was previouſly between the water and he paper, is between the ſurface of the ater and the glaſs. Now has not this air he ſame degree of elaſticity as the external ir?—Does it not conſequently exert an qual preſſure on the water?—And muſt not he preſſure from above and that from below alance each other, therefore, ſo that the ater will fall by it's own weight, as in the pen air?"

To this ſtring of queſtions we reply: The moment the glaſs is inverted, the r above the water poſſeſſes the ſame den- y and elaſticity as the external air; and, t this account, a ſmall quantity of water ways makes it's appearance between the per and the brim of the glaſs, as ſoon as e hand, that held the paper againſt the aſs, is removed. But with this ſinking wn of the water the ſpace above it is en- rged; conſequently, the air over it, being bliged by it's nature to expand itſelf rough a ſomewhat larger ſpace, has it's nſity and elaſticity proportionally diminiſh- ; for no *freſh air* can enter in, as it is ex- *ded by the interpoſition* of the paper."

"But the paper is not fixed to the brim of the glaſs ſo as to be air-tight."

"If it be not fixed to it, the ſpace between the glaſs and the paper is cloſed by the water that deſcended; and this ſpace is ſo ſmall, that the air is not able to overcome the attraction of cohefion between the particles of water included in it."

"How long, then, does the water continue to deſcend?"

"Till the air between the water and the glaſs is ſo far dilated, that it's diminiſhed elaſticity, added to the weight of the water, is exactly counterpoiſed by the preſſure of the external air.

"If you hold the inverted glaſs a little obliquely, you will find, that the water accumulated round the brim by the attraction of cohefion will deſcend toward the lower part, and that part of the brim which is higheſt being no longer defended by the external water, the air will preſs in, and aſcend in a ſmall bubble to the top. As every ſuch bubble increaſes the quantity of air within the glaſs, a proportionate quantity of water will be *found* to iſſue out of it at the lower part of *the brim*; and this will go on, till the glaſs

is emptied, unleſs you reſtore it to the perpendicular poſition again. It is the ſame thing, if you employ a trencher inſtead of a piece of paper; and with this you will ſee the water accumulated round the brim more perſpicuouſly."

There is a different mode of ſetting a glaſs upon a plate or ſaucer, ſo that a perſon cannot remove the glaſs without ſpilling the liquor in it.

Pour a certain quantity of water into a ſaucer, or ſoup-plate. Invert a glaſs over a piece of burning paper, or, which is better, over burning brandy, or ſpirit of wine; and, after holding it in this manner a ſhort time, ſet it in the ſaucer: the water will aſcend into the glaſs, and leave the ſaucer nearly dry.

To underſtand this, it muſt be obſerved, the air is at firſt greatly dilated in the glaſs by the heat of the flame. When the glaſs is ſet over the water, this air is cooled, it's elaſticity diminiſhes, and the external air preſſes the water into the glaſs. Care muſt be taken, however, that the glaſs is not made too hot, otherwiſe it will crack on being ſuddenly *cooled by the water.*

Thus, in the operation of cupping, a number of inciſions being made through the ſkin, a hollow glaſs veſſel, called from it's uſe a cupping-glaſs, is placed over them, the air in it being previouſly rarefied in the manner above-mentioned; and as this air condenſes by cooling, the preſſure of the external air forces the blood through the inciſions into the glaſs.

CHAP. XXIX.

ANOTHER CURIOUS EXPERIMENT.

To raiſe up a heavy metal mortar, or the like, with a wine glaſs.

HAVING inverted the mortar, ſpread on the bottom, or at leaſt where the brim of the glaſs is to be placed, a little paſte of flour and water. Then pour ſome ſpirit of wine into a ſmall cup, ſet it on fire, and hold the glaſs over it, ſo that the flame ſhall aſcend into the glaſs, and heat and dilate the air *within* it. When you ſuppoſe the air to be *ſufficiently* dilated, place the glaſs without

delay on the paſte, and preſs it tight againſt the bottom of the mortar, ſo that no air can preſs in from without. Let it remain thus, till the air within the glaſs is cooled; and then, if you lift up the glaſs, it will raiſe the mortar with it.

You may uſe a piece of wet leather inſtead of the paſte: but the paſte is better, becauſe the brims of common glaſſes are not always ſufficiently even, to preſs cloſe to the leather in every part, and a heated glaſs will be apt to crack, when it comes into contact with wet leather.

William, who was much delighted with the experiments deſcribed in this and the preceding chapters, becauſe he ſaw the principles of them, was deſirous of knowing the power, with which the mortar adhered to the glaſs.

Father. "There are two ways of finding this: by calculation, and by experiment. The following inſtructions will be ſufficient, to enable you, to make the calculation.

"The preſſure of the external air, you know, is equal to the weight of a column of water thirty-two feet high, the baſe of which is of the ſame dimenſions as the mouth of the

mouth of the glaſs, or of a column of air the height of the atmoſphere, which is the ſame thing, would be ſomething more than fifty-five pounds; and with this force would the glaſs be preſſed againſt the mortar.

Deducting from this the weight of the mortar, 10½ lbs., which the glaſs would have to raiſe, the force would ſtill be upwards of forty-four pounds: though leſs than this would be found on trial to ſeparate them; for the air remaining in the glaſs would poſſeſs a certain degree of elaſticity, which muſt be greater or leſs, according to the quantity expelled by the heat applied.

CHAP. XXX.

THE ILLUMINATED FOUNTAIN, AND FOUNTAIN OF FIRE.

WILLIAM was highly delighted one evening, when his father ſent for him into his ſtudy, at ſeeing on the table a double foun*tain, ſpouting* up two ſtreams of fire.

It's appearance was that of fig. 11. It conſiſted of a glaſs globe, with a hollow ſtem, from which iſſued two arms, that bent upward at the end, and terminated with very ſmall apertures. The tube was ſtopped with a cork, and ſet in a tin ſtand, which likewiſe had two arms, with a ſmall cup at the end of each. The globe was half full of ſpirit of wine; and ſpirit of wine was put into the cups, and kindled. The air within the globe, being heated by the flame, was in conſequence dilated, and preſſed with greater force upon the ſpirit, cauſing it to ſpout out of the aperture in each arm. Theſe apertures being directly over the cups, the ſpirit was ſet on fire by the flame, thus forming two jets of liquid fire, which had a very pleaſing appearance, in a room where there was no other light.

The illuminated fountain (fig. 12), which his father then ſhowed him, was another worked by means of heated air. It conſiſted of two tin veſſels, one over the other. The uppermoſt was ſupported by four pillars; one of which, being hollow, formed a communication between the two. The pillars were about *two feet high*; the veſſels, ſix inches *each, and nine* inches in diameter. Beneath *the upper veſſel* were four lamps burning

one faſtened to each pillar. From the centre of the lower veſſel roſe a tube with a narrowed opening, and furniſhed with a ſtop-cock. After the lamps had burned a little while, the cock was turned, and a ſlender ſtream of water ſpouted up, almoſt as high as the upper veſſel.

The lower veſſel had been previouſly filled with water, and then ſtopped cloſe, ſo as to have no communication with the external air. The upper veſſel was air-tight. Conſequently, when the air in the upper veſſel was rarefied by the heat, it preſſed upon the water in the lower veſſel by means of it's communication with it through the hollow pillar, and forced it up out of the tube, as ſoon as the cock was turned. Then the heat continuing to rarefy the air, the fountain continued playing, till the lamps were extinguiſhed, when it quickly ſtopped.

CHAP. XXXI.

MICROSCOPICAL AMUSEMENTS.

William to Henry.

DEAR HENRY,

IT is long ſince I wrote to you, but, to make you amends, I hope I ſhall now ſend you ſomething amuſing. Yeſterday our father entertained us with an exhibition of various things in the microſcope. Caroline had complained, that he had ſhown me ſo many curious things, which ſhe could not ſee, becauſe ſhe was buſied in the affairs of the houſe. Theſe, he told her, were objects of moſt importance to a girl; but, that ſhe might not be altogether without her ſhare, he would exhibit to us both ſome things, ſmall indeed in themſelves, but capable of exciting ideas of ample extent. Accordingly, it being a fine ſunſhiny day, he fixed his ſolar microſcope in the window ſhutter, and placed another mi-

croſcope on the table, for ſuch things as could not be ſeen ſo well through the former.

I requeſted him firſt to explain to us, how theſe inſtruments were made, and why they made things appear ſo large: but he told me, that I muſt wait for ſome other opportunity, and ſatisfy myſelf for the preſent with ſeeing the exhibition; which indeed afforded me a great deal of entertainment.

Of ſome of the articles I made drawings, as they appeared, to ſend to you.

The firſt object we ſaw under the microſcope was a piece of fine ſilk crape, about the ſize of a lentil (fig. 13). Fine as it appeared to the naked eye, it was as coarſe under the glaſs as the figure I have drawn. Caroline ſtared when ſhe ſaw the rough black cords, and their ragged appearance on the torn edges of the crape.

The next was a piece of *ſhot ſilk*, the warp of which was red, the weft blue, fig. 14. This appeared very regular, and pretty. The threads lay tolerably even and parallel; the fine fibres, of which each thread was compoſed, were very clearly to be ſeen; and be*tween the* threads were regular ſquare open-

ings, though the ſilk looked very cloſe to the eye.

Caroline then cut off a bit of a black ſattin riband, which looked very dingy, and it's texture obſcure.

"You ſee," ſaid our father, "how coarſe theſe fine and delicate performances of art appear. Now look at an object, which is the work of nature, and you will be aſtoniſhed, to ſee how nicely ſhe finiſhes the minuteſt parts, which are ſcarcely viſible to the eye aſſiſted by glaſſes." On this he took the foot of a dead fly, or rather the lower end of the leg, and placed it under the microſcope. How were we aſtoniſhed at ſeeing it! (fig. 16). There were four joints, and what might properly be called the foot. Each joint was thicker below, than where it was faſtened to the other above: each was furniſhed with hairs or briſtles; and at the lower end, where it projected over the next joint, were ſtrong prickles, pointing downward. The foot itſelf, or the lower end of it, had two balls, covered with extremely ſlender ſhort hairs, like a fine down, but thicker on the under part than the upper; and at the ſide of each was a ſharp, crooked claw. The fine down,

ſeen in a certain poſition toward the light, appeared of a beautiful ſky-blue colour: but this, our father ſaid, might be owing merely to the refraction of the rays of light. We looked at this foot when magnified by the ſolar microſcope alſo, and then it appeared as big as the foot of an eagle.

"See," ſaid our father, "how much more abundant matter for reflection is afforded by the ſmalleſt objects of nature, than by the moſt elaborate performances of man. Conſider the ſlenderneſs of theſe hairs, that cover the foot, which are ſcarcely viſible when ſo greatly magnified. Conſider the fineneſs of the veſſels, which there muſt be in this limb, to ſupply it with nouriſhment, as we have arteries in our legs. Conſider how curiouſly it is framed for it's office. Here are ſeveral joints, connected one to the other, and moveable as our leg at the knee, nay capable of more extenſive motion. By means of theſe, the fly ſprings up with great velocity, when it would take wing. See how providently the foot is furniſhed with claws, to render it eaſy for the inſect to hold itſelf ſecurely, when it walks up the perpendicular wall, or even along the ceiling. The fineneſs of the points,

in which they terminate, renders it practicable for the fly, to faſten itſelf even to the glaſs of the window, which is perpendicular, or the looking-glaſs hanging againſt the wall; for though their ſurface appears to us perfectly ſmooth, it affords hold for theſe ſlender hooks."

Little bits of Caroline's fine flaxen hair appeared under the microſcope as big as the barrels of large quills, fig. 17, and hollow within. Seen by means of the ſolar microſcope they were like large poles, and their tubular ſtructure was more conſpicuous.

Caroline thought of looking at her needle through the microſcope. She wondered how fine the point muſt be, with which ſhe could ſew ſo quickly and ſo neatly: and was not a little ſurpriſed, to ſee how huge it appeared in compariſon with the claws and briſtles of the fly's foot. It looked like a thick iron bolt, rough from the ſmith's hand (fig. 18); and the point was blunt and rounded, ſo that it ſeemed impoſſible for it to pierce the ſkin.

But the moſt beautiful of all was a little bit of one of the wingcaſes of a cock-chafer. Looking at it firſt with the naked eye, we *ſaw nothing but* a bit of a thin light-brown

ſubſtance, in which we could not ſuppoſe there was any thing ſingular. But we were agreeably deceived, when we looked into the microſcope. The piece then, as much of it as we could ſee, was of a golden colour, ſpotted like the ſkin of a leopard, with a brown and yellow border, as at fig. 19. Brown, annular ſpots were ſcattered over the yellow ſurface; and on the edge, that was not torn, were three brown ſtripes. When the light of the Sun was ſuffered to fall upon it through the glaſs, the brilliancy was beyond deſcription. fine, but ſo dazzling, that, to ſee it clearly, it was neceſſary to moderate the light. The ſolar microſcope exhibited it in a very ſplendid manner, and from that my drawing was made, which, however, is far ſhort of the beauty of the original.

Your affectionate brother,

WILLIAM GOODWIN.

CHAP. XXXII.

THE FIRE OF BAKU.

THE city of Baku, or Badku, on the borders of the Caſpian ſea, and about three miles from the ſouthern arm of the Caucaſean mountains, is ſeated in a delightful country, part of which has ever been diſtinguiſhed by the name of the Paradiſe of Roſes. It has long been famous for it's ſprings of *naphtha*, a ſpecies of bitumen, or foſſil oil, which, when pure, is white, very light, very fluid, and highly inflammable.

About two miles eaſt from one of the pureſt naphtha ſprings is a very ſingular ſpot, called *Atoſhyah*, or the *Place of Fire*. On approaching this place a ſtrong ſmell of ſulphur is perceived. The place itſelf is near three quarters of a mile over; and in the middle of it, when the weather is dry, may be perceived a ſtrong bluiſh yellow flame, which appears larger by night than by day. At a little diſtance from this flame, the guebres, *or gebers*, an aſiatic people, who worſhip fire,

and other poor perſons, have built little ſtone habitations. The ground within the ſingle room, which theſe huts contain, is covered with a floor of clay a foot thick, rammed down hard, that the flame may not burſt through. In one place, however, a hole is left in the clay floor, to furniſh fire when neceſſary; and when the hoſt has occaſion to boil his coffee, or dreſs his food, he holds a lighted candle, or a bit of burning paper over the hole, and a flame is immediately produced, which he knows how to employ for his purpoſe better than he would a fire made with coals or wood. The ſmaller the opening is, with the more force riſes the flame. From an opening of two inches diameter it reached at firſt a height of three feet ten inches, but afterward fell to two feet five. When the fire is no longer wanted, the hoſt blows it out with a fan, or the flap of his garment, and then covers the hole.

Theſe people procure light in the ſame manner. Into a ſlender hole made through the clay floor they ſtick a reed, of ſuch height as they think proper, previouſly coated both on the inſide and outſide with clay, and kindle the vapour as it iſſues out at the top.

The weavers have ſeveral ſuch round their looms, which afford them an ample ſupply of light, without requiring to be trimmed or renewed.

This fire is not wanted to yield warmth in winter, for in that climate it is ſufficiently hot for the people to leave their doors open all the year round.

Beſide this conſuming fire, there is another kind at Baku, which does not burn. When, after a warm autumnal rain, the evening air is warm likewiſe, the fields round Baku appear in flames. It frequently ſeems as if huge volumes of fire rolled down the mountains with incredible velocity. In October and November, on clear moonlight nights, all the mountains weſt of Baku often appear enveloped in a blue flame. In warm and dark nights, innumerable flames, ſometimes ſeparate, ſometimes united together, cover the plains; and then the mountains are free from them. Theſe frequently fill the ſpace where a caravan has encamped, to the great terrour of the horſes and mules.

This fire burns nothing. The dry graſs and reeds remain unſinged, though the whole country appears in flames. It does not even

yield the leaſt heat. This fire, as it is called, muſt be merely a luminous appearance therefore, and totally diſtinct from the former.

It is to be obſerved, that light and heat, though they are ſo commonly found together, and appear on different occaſions capable of mutually producing each other, ſo that the ideas of both become almoſt inſeparably aſſociated in our minds with that of fire, are probably to be conſidered as perfectly diſtinct from each other; and we are told, that the celebrated Dr. Herſchel has lately diſcovered a method of ſeparating them.

A remarkable circumſtance, reſpecting the fire, or more properly the light, of which we have been ſpeaking, is, that it will remain for ſome minutes attached to the outſide of a glaſs exhauſted of air, like a phoſphoreſcent appearance. Exhauſted glaſs tubes appear ſtrongly luminous, and as if filled with fire, for ſome minutes after the flame in the open air is extinguiſhed: whence we may infer, that electricity has a ſhare in this ſingular phenomenon.

CHAP. XXXIII.

AN EXTRAORDINARY EATER.

MANY of our readers, no doubt, have heard of a ſtone-eater, as he was called; a man who gained a livelihood by going about as a ſhow, ſwallowing pebbles, and champing to pieces and ſwallowing bits of ſtone. We do not know the fate of this man; though it does not appear, that he lived long under this practice. The human ſtomach can accommodate itſelf occaſionally to improper ſubſtances in a wonderful manner, ſo that every accidental ſwallowing of an indigeſtible ſubſtance is not neceſſarily fatal: but this can never be practiſed long with impunity; and inſtances of ſuch violent ſuffering from a ſingle imprudence of the kind have been known, that we cannot be too cautious, in never allowing ourſelves even to hold in the mouth a pin, a pebble, or even a plum-ſtone, much leſs to ſwallow them. A ſtill more extraordinary inſtance than that of the ſtone-eater, however, is the following; the ſubject of

which ſuffered much from his imprudence, and at length fell a victim to it.

Andrew Baſile, a galley-ſlave at Breſt, came into the naval hoſpital on the 5th of September, 1774. He complained of a cough, oppreſſion at the ſtomach, and pains in the bowels, for which Dr. de Courcelles, the hoſpital phyſician, preſcribed ſome medicines, that ſeemed to mitigate his complaints. He was ſtill in the hoſpital in the beginning of October, when he fell under the care of another phyſician, Dr. Fournier. He was then tormented with pains in his ſtomach, and frequent vomiting, which rendered him very low: but the phyſician obtained no information from him, that could lead to a knowledge of the cauſe of his diſorder; and accordingly preſcribed ſuch medicines, as he judged to be moſt ſuitable to his complaints. On the 10th of October he died.

Dr. Fournier conjectured, that he muſt have had ſome peculiar affection of the internal parts, and the next day opened the body. The ſtomach appeared to be thruſt out of it's uſual ſituation, and various hard ſubſtances were felt in it, though what they were could not be aſcertained by the feel-

Through an accidental opening made in it, however, Dr. Fournier ſaw a piece of wood, of a black colour, protrude; and in conſequence he deferred any farther examination of this ſingular caſe, till the arrival of a company of phyſicians, ſurgeons, pupils, and officers, whom he invited to be preſent. At three o'clock they were all aſſembled, to the number of fifty, and in the preſence of theſe eyewitneſſes, an account of the whole was drawn up. The ſtomach, as well as the œſophagus and bowels, was internally of a blackiſh colour, and the following is an inventory of the articles it contained.

1. A piece of an iron hoop, nineteen inches long, and an inch broad.

2. A piece of broom, ſix inches long, and half an inch thick.

3. Another piece, of the ſame thickneſs, eight inches long.

4. Another ſuch piece, ſix inches long.

5. Another, four inches long.

6. Another piece, four inches long, ſplit nearly in the middle.

7. A piece of oak, four inches and half long, an inch and half broad, and half an inch thick.

8. Another piece, four inches long, an inch broad, and two thirds of an inch thick.

9. Another piece, four inches long, half an inch wide, and a third of an inch thick.

10. Another piece of the ſame dimenſions.

11. Another piece, two inches long, an inch broad, and half an inch thick.

12. Another piece, four inches and half long, a third of an inch broad, and a third of an inch thick.

13. Another piece, four inches long, and of a triangular figure.

14. Another piece, four inches long, and a third of an inch in diameter.

15. Another piece, five inches long, half an inch broad, and two lines thick, ſplit lengthwiſe.

16. Another piece, five inches long, a third of an inch broad, and two lines thick.

17. Another piece, of an irregular figure, three inches long, and a quarter of an inch thick.

18. Another piece, three inches long, half an inch broad, and a quarter of an inch thick.

19. A piece of a hoop, five inches long, an inch broad, and two lines thick.

20. A piece of fir, four inches long, an inch broad, and near half an inch thick.

21. Another piece, four inches long, and a third of an inch in diameter.

22. Another piece, in the ſhape of a wedge, two inches and half long, one inch broad, and a third of an inch thick at the baſe.

23. Another piece, of an irregular figure, three inches long, and half an inch thick.

24. Another piece, two inches and half long, and a third of an inch thick.

25. A piece of bark from a hoop, three inches and half long, and an inch broad, belonging to a larger piece, which ſtill ſtuck in the œſophagus, and from which this had been broken off, and fallen into the ſtomach.

26. A wooden bung, an inch long, and the ſame in diameter.

27. A wooden ſpoon, gnawed at the lower end, five inches long, and an inch and half broad.

28. The noſle of a tin funnel, three inches and half long, an inch in diameter at the larger end, and half an inch at the ſmaller.

29. Another piece of a tin funnel, two inches and half long, and half an inch thick.

30. The handle of a pewter ſpoon, four inches and half long.

31. A pewter ſpoon entire, ſeven inches long, the bowl bent round.

32. A ſmaller ſpoon of the ſame metal, three inches long.

33. Another, two inches and half long.

34. A piece of iron, two inches and half long, half an inch broad, and a third of an inch thick.

35. A pipe-caſe, with the edges blunted, and a piece of the ſtem, all together three inches long.

36. A nail, the point broken off, two inches long, including the head.

37. Another nail, very ſharp, an inch and half long.

38. A piece of a pewter ſpoon, ſqueezed flat, an inch long, and half an inch broad.

39. Two pieces of a pewter buckle, of irregular figures, each about half an inch long.

40. Five plumb-ſtones.

41. A little piece of horn.

42. Two pieces of flint glaſs, the largeſt an inch and one third long, half an inch broad, and of an irregular ſhape.

43. Two pieces of leather, the largeſt three inches long, an inch broad, and of an irregular figure; the other an inch and a third long, and half an inch broad.

44. A knife, with it's blade bent, the haft of wood, three inches and half long, and an inch broad in the wideſt part.

Thus the whole of this ſingular ſtore conſiſted of fifty two articles, weighing above two pounds.

One of his countrymen, who had been ſent to the galleys with him, ſaid, that he had often ſeen him ſcratch down mortar and plaſter from the wall, and throw it into his ſoup, ſaying, that it was a cordial to him, and comforted his heart. Sometimes he had a raging appetite, which announced itſelf by an abundant flow of ſpittle, and could then eat as much as four people. When this was the caſe, and he could not ſatisfy his hunger, becauſe he had ſpent his money in tobacco, of which he was very fond, he uſed to ſwallow little ſtones, buttons, pieces of leather, and other ſuch things. His comrades at the oar had ſeen him ſwallow two pieces of wood, *four or five inches* long, two days before he *went to the hoſpital*: but it was not known

when he had ſwallowed the great piece of an iron hoop nineteen inches in length. He long complained of pains in his inſide; but had never mentioned any thing relative to his ſingular diet, except once ſaying, that he had a thouſand deviliſh things within him, which would be his death. At times, however, he appeared to be diſordered in his mind.

CHAP. XXXIV.

SPONTANEOUS COMBUSTIONS.

It has long been known to chymiſts, that there are ſubſtances, which, though perfectly cold, when mixed produced heat, and even actual fire. Thus in the curious experiment called Lemery's volcano, a large quantity of iron-filings and flowers of ſulphur, being mixed with ſo much water as will make it into a paſte, and then buried in a hole in the ground, will grow hot, and after a time cauſe the earth over it to ſwell up, till at laſt it cracks, and flames iſſue out.

Of late years, however, ſome ſerious accidents have called the attention of men of ſcience to the ſubject, and it has been found, that many other ſubſtances, when mixed together, or packed up cloſe, or expoſed to a certain degree of warmth, grow very hot. Ricks of green hay, and dunghills, ſometimes grow ſo hot, as to take fire ſpontaneouſly; and greaſy cloth laid in heaps together, various articles that have been roaſted, and other things, are liable to the ſame danger. Many fires may have been occaſioned in this way, that were afterward attributed to malicious deſign, becauſe the manner in which they were produced could not be diſcovered. It is not ſufficient, to take care of fire and candle, though this is highly neceſſary; for there are many other things, of which we ought to be as careful, though neither fire nor light is apparent in them. The following are examples.

At a ſail-cloth manufactory ſeveral pieces of coarſe hempen canvas, painted on one ſide with brown paint mixed with oil, were laid in the ſun to dry. It was a very hot day in July, ſo that it dried very quickly, and was *conſiderably* heated; when, in the afternoon,

there being an appearance of a heavy ſtorm, it was haſtily taken in, the painted ſides being laid one upon the other, and the whole being folded up in bales, and tied tightly together, to remove it more conveniently. Theſe bales were placed in the workſhop, which was ſhut up at night.

Two days after, one of the workmen ſat down upon theſe bales, and found them hot. He thruſt his hand in between the folds, but the heat ſoon made him draw it out again. The bales were taken into the open air, and as ſoon as the men began to unpack them, a thick ſmoke iſſued out. It was at firſt ſuppoſed, that they had been purpoſely ſet on fire: but no trace of ſuch a thing could be found, and, as ſoon as they were completely unfolded, all ſuſpicion vaniſhed; for it was clearly ſeen, that the fire began in the centre of the bales, the outſide remaining untouched, while the inner folds, particularly where preſſed together tightly by the cords, were burned to aſhes.

Some of the workmen then confeſſed, that a ſimilar accident had happened a few years before, which they had concealed, for fear it

would be aſcribed to their negligence, and they be puniſhed.

Similar inſtances have occurred more than once with woollen cloth, the wool for which is well oiled before it is carded and ſpun. Various pieces of ſerge, being laid upon one another, without being cleanſed from the oil, heated to ſuch a degree, that the undermoſt, without emitting either flame or ſmoke, were converted into a black, ſhining, brittle ſubſtance, which ſmelled like burnt horn, melted over the fire, and burned with a flame like reſin.

A mixture of linſeed oil and lampblack is a very dangerous combuſtible.

In Auguſt 1780 a fire broke out in a warehouſe at Peterſburg, by which a great quantity of hemp was conſumed. On inquiry there appeared reaſon to ſuppoſe, that it was occaſioned by a mixture of this kind. To obtain ſtrong aſſurance of the fact, five and thirty pounds of hemp-ſeed oil varniſh were poured upon forty pounds of lampblack in a tub, under the inſpection of the imperial academy. After ſtanding an hour, the ſuperfluous oil was poured off. The reſiduum was left in the tub four hours, then rolled up

in a hammock, and laid in a ſhip's cabin, where a ſuſpicious fire had broken out, which was ſaid to have been produced by ſuch materials. The door was ſealed up, a guard ſet over it, and four naval officers were directed to watch the appearances attentively all night. The experiment was begun on the 26th of April, 1781, at eleven o'clock in the forenoon. The next morning at ſix ſmoke appeared iſſuing out of the hammock, and, as ſoon as the door was opened, it burſt into flames.

The admiralty directed another experiment to be tried. Three pounds of lampblack were ſlowly mixed with five pounds of hempſeed oil varniſh; and after the mixture had ſtood five hours in an open veſſel, it was tied up in linen, and placed in a box. Sixteen hours after an offenſive, ſtinking ſmell was perceived, but not like that of boiling oil. Some parts had grown hot before this. The vapour, that aroſe, was not inflammable, but watery. Eighteen hours after the mixture had been packed up, more places grew hot, began to ſmoke, and ſoon after appeared *glowing* with fire. Other places ſtill were *ſcarcely* warm. The fire ſpread in the mix-

ture but ſlowly, and emitted a thick, dark, ſtinking, ſooty vapour. When the bundle was taken out of the box, and laid on the ſtone floor, ſo that the air had free acceſs to it, flames burſt out, with thick ſmoke. Soon after clefts appeared here and there, from which iſſued vapours, that ſoon roſe into flame. On breaking the lumps a little, they burſt into a violent flame, near a yard high, but it ſoon diminiſhed, and went out. The ſmoking, glowing, and flaming fire, however, continued for ſix hours; and the maſs remained redhot for two hours after this. The gray, earthy aſhes, that were left, weighed, when cold, three ounces and half.

A perfectly ſimilar mixture being made, the fire did not take place till one and forty hours after.

A pack of hemp weighing thirty pounds was greaſed with a mixture of ſix pounds of hemp-ſeed oil and a pound of tallow, placed in an oven for an hour, rolled up in a mat previouſly warmed, and laid on ſome faggots. In an hour's time the pack began to heat; in three hours it emitted ſmoke. Being opened, it appeared on fire in two places; burned four hours with flame; and then continued glow-

ing, till in thirty two hours it was reduced to aſhes.

Twenty pounds of wool were greaſed with a mixture of two pounds of hemp-ſeed oil, and one pound of tallow. The wool was placed in an oven for an hour, and then tied up in a warm mat. The bundle remained cold three days, the wool having abſorbed all the greaſe. Another pound of hemp-ſeed oil, therefore, was poured on it; it was put into the oven again for an hour; and, being tied up in a coarſe cloth, was laid on ſome faggots. It now began to ſmoke, and in four hours time was on fire. The fire burned without flame, as long as the pack remained tied up; but as ſoon as it was opened, a low flame iſſued from it. After it had continued burning forty hours, the fire went out.

Old cloth garments drenched with hemp-ſeed oil, dried in an oven, and rolled up together, remained without heating. But when, in addition to this, they were greaſed with tallow, put into the oven afreſh, and again rolled up, they grew hot, in three hours time ſmoked, and in four and twenty hours the *bundle* was found charred and ſmouldering.

At length it took fire, and was four days before it had burned out.

Cow's hair, beſmeared with tallow, warmed in the oven, and put into a bag of matting, grew hot in an hour and a quarter. It began to ſtink, to ſmoke, and in an hour after burſt into flames.

A quantity of rye bran, weighing two pounds, was roaſted in an old copper pot, on a coal fire, ſtirring it conſtantly, till it was as brown as pale coffee; when it was poured out hot into a piece of linen, and tied up in it. In three hours heat and ſmoke were perceived, ſome ſpots burned black appeared, then glowing fire, and this continued ſix hours. On repeated trials, the browner the bran was roaſted, the ſooner it caught fire.

Rye flower, and wheaten flower, roaſted like coffee, and tied up in linen, took fire in ſeven minutes after they were packed up: pearl barley, in half an hour: and barley-meal, in fourteen hours.

Rice, roaſted very brown, and packed up, was merely charred, and the outſide ſcaled off.

Peaſe, roaſted, pounded, and packed up, *burned fiercely in half* an hour.

Coffee berries, roaſted, and packed up, did not take fire. But when they were firſt roaſted, then ground, afterward roaſted again, and packed up hot in a linen cloth, the coffee took fire in three quarters of an hour.

Beans, roaſted, and packed up, did not take fire: but bean-meal, treated in the ſame manner, did.

Various kinds of herbs, dried, powdered, roaſted brown, and packed up, took fire in a longer or ſhorter time.

Coarſe ſawduſt, roaſted and packed up, took fire in an hour.

Hence it appears, how dangerous many things of this kind may prove; and how much precaution is neceſſary on many occaſions, where commonly nothing is apprehended.

CHAP. XXXV.

SPONTANEOUS COMBUSTIONS OF THE HUMAN BODY.

It has been ſeen in the preceding chapter, that various ſubſtances, or combinations of ſubſtances, under certain circumſtances, are diſpoſed to generate heat, even to ſuch a degree as to conſume themſelves. But, what is more ſurpriſing, and would indeed be incredible, were it not confirmed in more inſtances than one by teſtimonies of ſuch authenticity, that we cannot refuſe our belief, our own bodies, while living, may become ſo combuſtible, as to burn away without the aid of extraneous fuel; nay, it ſhould ſeem, they may even be conſumed by fire, ſpontaneouſly generated within them.

In the Tranſactions of the Royal Society of Copenhagen we read, that, in 1692, a woman of the lower claſs, who for three years had uſed ſpirituous liquors to ſuch exceſs, *that ſhe took* ſcarcely any other nouriſhment, *having ſitten* down one evening in a ſtraw-

chair to ſleep, was conſumed in the night-time, ſo that next morning no part of her was found but the ſcull, and the extreme joints of the fingers, all the reſt of her body being reduced to aſhes.

Bianchini, a celebrated phyſician of Verona, relates the following caſe very circumſtantially. It is atteſted alſo by the marquis Scipio Maffei, a learned contemporary of Bianchini, who was far from being credulous; and was confirmed to the Royal Society of London by Paul Rolli.

The counteſs Cornelia Bandi, of Ceſena, aged 62, enjoyed a good ſtate of health. One evening, having experienced a ſort of drowſineſs, ſhe retired to bed, and her maid remained with her, till ſhe fell aſleep. Next morning, when the girl entered her miſtreſs's chamber to awaken her, ſhe found nothing but the remains of her body in a horrid condition. At the diſtance of four feet from the bed lay a heap of aſhes, amid which were the arms, and the legs with the ſtockings on them. Between the legs lay the head; but the brain, half the hinder part of the ſcull, and the whole of the chin, were conſumed. Three fingers were found burned to a coal

the reſt of the body was reduced to aſhes, which, when touched, left on the fingers a greaſy, fetid moiſture. A ſmall lamp, which ſtood on the floor, was covered with aſhes, and contained no oil; the tallow of two candles was melted on a table, but the wicks ſtill remained. The bed was not damaged; and the bedclothes had been lifted up, and thrown on one ſide, as when a perſon gets out of bed. The floor was covered with a thick, ſlippery moiſture, which adhered to it very tenaciouſly. The furniture and tapeſtry were covered with a moiſt kind of ſoot of the colour of aſhes, which had penetrated into the drawers, and ſoiled the linen. This ſoot had diffuſed itſelf into a kitchen adjoining, adhered to the walls and utenſils, and covered a piece of bread in the cupboard, which no dog would touch. In the chamber over the apartment of the counteſs, a yellowiſh, greaſy, offenſive fluid trickled down from the windows. The air in it likewiſe was loaded with that fine ſoot, and an unuſual offenſive ſmell: and this noiſome odour gradually ſpread into the adjacent apartments.

We do not know how far the counteſs had *been addicted to* the internal uſe of ſpirituous

liquors, but ſhe had been accuſtomed to have her body bathed all over with camphorated ſpirit of wine.

A third example, we ſhall mention, occurred in France; and the following is the report of it, drawn up by Mr. Merille, a ſurgeon of Caen, at the requeſt of the officers appointed to examine into the fact.

"The body of Mrs. Thuars lay with the crown of the head reſting againſt one of the andirons, at the diſtance of eighteen inches from the fire: the remainder of the body was in an oblique poſition before the fireplace, the whole being a heap of aſhes. Even the moſt ſolid bones had loſt their firm conſiſtence; ſo that none were diſtinguiſhable, except the coronal, the two parietal bones, two of the lumbar vertebræ, part of the tibia, or large bone of the leg, and a part of the ſcapula or bladebone; and theſe were ſo calcined, that they crumbled to duſt on the leaſt preſſure. The feet, however, remained; but the right was ſcorched at the upper joint, and the left was more burnt. The day had been cold, but there was nothing in the grate, *except two* or three bits of wood, about an *inch in diameter*, burnt in the middle. None

of the furniture in the apartment was damaged. The chair, on which Mrs. Thuars had been ſitting, was found at the diſtance of a foot from her, and abſolutely untouched. I muſt here obſerve, that this lady was exceedingly corpulent, above ſixty years of age, and much addicted to ſpirituous liquors; that on the day of her death ſhe had drunk three bottles of wine, and about a bottle of brandy; and that the conſumption of the body had taken place in leſs than ſeven hours, though, according to appearance, nothing around the body was burnt but the clothes."

Many other caſes are on record, more or leſs circumſtantially related, and more or leſs credibly authenticated, but we ſhall conclude with two, that happened in this country, and appear to be ſufficiently confirmed.

Grace Pitt, the wife of a fiſhmonger of Ipſwich, about ſixty years of age, had contracted a habit, which ſhe continued for ſeveral years, of coming down every night from her bed-room, half dreſſed, to ſmoke a pipe. On the night of the 9th of April, 1744, ſhe got up from bed as uſual. Her daughter, who ſlept with her, did not perceive ſhe was abſent, till next morning, when ſhe awoke;

ſoon after which ſhe put on her clothes, and went down to the kitchen, where ſhe found her mother, ſtretched out on her right ſide, with her head near the grate, the body, having the appearance of a log of wood, conſumed by a fire without apparent flame, extended on the hearth, and her legs on the floor, which was of deal. On beholding this ſpectacle, the girl ran in great haſte, and poured over her mother's body ſome water, contained in two large veſſels, in order to extinguiſh the fire; while the fetid odour and ſmoke, which exhaled from the body, almoſt ſuffocated ſome of the neighbours, who had haſtened to the girl's aſſiſtance. The trunk was in ſome meaſure incinerated, and reſembled a heap of coal, covered with white aſhes. The head, the arms, the thighs, and the legs, had alſo participated in the burning. This woman, it is ſaid, had drunk a large quantity of ſpirituous liquors, in conſequence of being overjoyed, to hear that one of her daughters had returned from Gibraltar. There was no fire in the grate, and the candle had burned entirely out in the ſocket of the candleſtick, which was *cloſe to* her. Beſides, there were found near *the* conſumed body the clothes of a child

and a paper ſcreen, which had ſuſtained no injury by the fire. The dreſs of this woman conſiſted of a cotton gown.

Mary Clues, fifty years of age, was much addicted to intoxication. Her propenſity to this vice had increaſed after the death of her huſband, which happened a year and half before. For about a year, ſcarcely a day had paſſed, in the courſe of which ſhe did not drink at leaſt half a pint of rum, or aniſeed water. Her health gradually declined, and about the beginning of February ſhe was attacked by the jaundice, and confined to her bed. Though ſhe was incapable of much action, and not in a condition to work, ſhe ſtill continued her old habit of drinking every day, and ſmoking a pipe of tobacco. The bed, in which ſhe lay, ſtood parallel to the chimney of the apartment, and about three feet diſtant from it. On Saturday morning, the 1ſt of March, ſhe fell on the floor; and her extreme weakneſs preventing her from getting up, ſhe remained in that ſtate, till ſome perſon entered, and put her into bed. The following night ſhe wiſhed to be left alone. A woman quitted her at half after eleven, ſhut the door, and locked

it, according to cuſtom. She had put on the fire two large pieces of coal, and placed a light in a candleſtick on a chair at the head of her bed. At half after five in the morning a ſmoke was ſeen iſſuing through the window, and the door being ſpeedily broken open, ſome flames, which were in the room, were ſoon extinguiſhed. Between the bed and the fireplace were found the remains of the unfortunate woman. One leg and a thigh were ſtill entire; but nothing was left of the ſkin, the muſcles, and the inteſtines. The bones of the ſcull, body, and arms, were wholly calcined, and covered with whitiſh aſhes. The people were much ſurpriſed, that the furniture had ſuſtained ſo little injury. The ſide of the bedſtead next to the chimney had ſuffered moſt, the wood being ſlightly burnt: but the featherbed and clothes were ſafe. Mr. Wilmer, a Surgeon of Coventry, from whom the above account is taken, ſays, that he entered the apartment about two hours after it had been opened, and obſerved, that the walls and every thing in it were blackened, and that it was filled with a very *diſagreeable* vapour, though nothing except *the body* exhibited any ſtrong traces of fire.

In each of theſe caſes, and all the others recorded, the perſons, to whom theſe diſtreſſing accidents happened, had been notoriouſly addicted to the drinking of ſtrong liquors; one excepted, the counteſs Bianchini; and ſhe, of whom nothing of this kind is ſaid, was accuſtomed to bathe the body all over with camphorated ſpirit of wine. The inflammable matter, therefore, furniſhed by theſe liquors, appears to have been the chief cauſe of the extraordinary combuſtibility of theſe unhappy perſons, whoſe fate may ſerve as an additional warning againſt the uſe of intoxicating liquors, which have occaſioned more bodily diſeaſe, and mental infirmity, than any thing elſe produced by nature, or invented by man.

CHAP. XXXVI.

DOES MAN SWIM BY NATURE?

THIS queſtion, put in this general manner, does not well admit of a direct anſwer: we will enter into the ſubject, therefore, a little more particularly.

Is a man ſpecifically lighter than water?

To ſolve this queſtion, it is requiſite, to make a number of experiments with perſons of different ages, and different make. Experiments of this kind are attended with difficulty, and we have too few of them. The following of Mr. Robertſon are the beſt.

He took a water-caſk, ſix feet and half high, and two feet and half in diameter at each end. Ten perſons, different in height and bigneſs, ſubmitted to the experiment. He would willingly have had them ſo, that there ſhould have been a fat man and a lean man of each different height; but he could not get them exactly as he wiſhed. A proper quantity of water being put into the caſk, which ſtood upright on one end, each of the perſons was immerſed in it, and the height, to which the water roſe, was meaſured. The height of the water before the perſon's immerſion being deducted from this, the remainder gave the cubical contents of the body immerſed; from which, and the abſolute weight of the body, the ſpecific gravity was eaſy to be found.

The following table exhibits the reſults of theſe experiments.

Their abſolute weight.	Weight of the water diſplaced by them.
161lbs.	160.8lbs.
147	161.6
156	156.6
140	172.6
158	183.7
158	176
140	170.1
132	156.6
121	151.5
146	146.9

hus, of theſe ten men, one only appeared
: a little heavier than water; all the reſt
lighter, and ſome indeed much lighter.
cannot rely implicitly on theſe experi-
ts, however; for Mr. Robertſon con-
s, that they were not ſo perfect, as might
been wiſhed. The perſons were im-
ent to get out; would not remain long
igh with the head under water; and
up quickly, ſo that the ſurface of the
r was not ſuffered to come to a perfect
. In conſequence, the height of the
r was not meaſured with ſufficient ac-
cy.

rom theſe experiments, however, it ſuf-
ficiently appears, that the human body in

general is at leaſt as light, if not lighter, than water. A thin, rawboned perſon may perhaps be a little heavier than water, than freſh water at leaſt: while thoſe who are fat, and whoſe bones are ſlender, will probably be found much lighter. If a perſon bathing let himſelf ſink in the water, where it is not too ſhallow, and remain motionleſs, he will find himſelf carried along by the ſtream, without ſinking to the bottom. In ſuch experiments ſome difference is made by inſpiring or expiring before ſtopping the breath; for when the lungs are full of air they occupy more room by ſome inches, and thus diminiſh the ſpecific gravity of the body.

But the queſtion, whether man ſwim naturally, does not turn on his ſpecific gravity alone. Man cannot live without breathing. If, therefore, he be not heavy enough, to ſink to the bottom, when wholly or nearly immerſed in water, this is not ſufficient. The head muſt be ſo far out of water, that he can breathe through the noſe at leaſt, if not through the mouth, or he will be ſuffocated. Moſt people will find the exertion *of ſome* power neceſſary to effect this; and *muſt* therefore move their limbs in ſuch

anner, that the reſiſtance of the water to
eir effort ſhall impel the body upward again
en ſinking. If the hands and feet be
oved in a perpendicular direction, this will
ectually keep the head above water, but
will not produce any change of place. For
is purpoſe it is neceſſary, that the hands,
feet, or both, be moved in an oblique
rection, which will impel the body for-
rd, at the ſame time that it raiſes it in the
ter.

A man may ſwim either in a perpendi-
lar poſition, or in a poſition nearly hori-
ntal. In the latter caſe he may ſwim
her on his back or on his belly.—
imming in a perpendicular poſition has
: advantage of being a poſture, to which
in is accuſtomed, and in which he may
ve his limbs nearly as in walking: hy-
ſtatically conſidered, however, it has the
advantage of requiring the whole head to
kept above water, which is not neceſſary
ſwimming on the back; and the ſwimmer
not employ his exertions with ſo good
ct to propel himſelf forward, as in the in-
ed *poſition, while* at the ſame time his
reſs *is retarded* by the reſiſtance of the

water to a greater ſurface. The art of keeping the body perpendicular, by moving the feet alone directly upward and downward, the hands remaining at reſt, is called treading water.

Swimming on the belly is perhaps the moſt laborious mode, becauſe the body is in an unuſual poſture, and the limbs are employed in a manner, to which they have not been accuſtomed. It is the beſt, however, for advancing forward, becauſe the efforts of both hands and arms are employed to moſt advantage, and the reſiſtance of the water is but ſmall. The nearer the body is to a horizontal poſition, the leſs this reſiſtance, and the greater the propelling power. In this mode, however, it is equally neceſſary, to keep the head above water.

Swimming on the back is the eaſieſt mode of all, becauſe in this poſition the greater part of the head may be under water, for, if the noſe and mouth be above the ſurface, it is ſufficient. Hence, as very little of the body is to be kept above water, little effort is required for this. In this poſition the feet can act very efficaciouſly, but the hands have little power, to propel the body forward.

As it is not our buſineſs here, however, to teach the art of ſwimming, but to explain it's phyſical principles, we muſt refer for farther inſtructions to Bernardi's Treatiſe on Swimming*, Salzmann's Gymnaſtics for Youth†, and the Encyclopedia of Bodily Exerciſes§.

CHAP. XXXVII.

ARTIFICIAL HELPS FOR SWIMMING.

SWIMMING is ſuch an agreeable exerciſe, that many, who have not ſufficient ſkill, to keep themſelves properly above water, would gladly participate in the healthful amuſement it affords. It is laborious, likewiſe, to thoſe,

* This is a german book; but there is an engliſh tranſlation of a little treatiſe on the art by Thevenot, which is a uſeful tract.

† A tranſlation of this work has been publiſhed by J. Johnſon, St. Paul's Churchyard.

§ *This is a* german work, in 3 large vols. 8vo, by *the author of the* Pleaſing Preceptor.

to whom conſiderable practice has not rendered eaſy the movements it requires. Some, too, have been afraid, to rely entirely on their own powers, leſt the cramp, or any other accident, ſhould ſuddenly deprive them of the capacity of exerting them. Hence long ago men began to turn their minds to artificial helps, capable of ſuſtaining them in the water without any action of their own, ſo that they ſhould have no occaſion for exerting any power, except to impel themſelves forward, and might reſt whenever they pleaſed.

Theſe helps may be divided into two claſſes: ſuch as ſwim, and help to ſupport the body, by their little ſpecific gravity; and ſuch as produce the ſame effect by their form.

To the firſt claſs belong cork, light wood, reeds, and the like, placed under or about the breaſt. Of theſe, cork is particularly ſerviceable, from it's little ſpecific gravity, as it has not one fourth of the weight of water. A well dried piece of cork, indeed, will not ſink above a ſixth or eighth part of it's bulk in water: but when it is uſed for ſwimming, the body it ſupports will preſs it down, and

the water will infinuate itſelf into the large interſtices, expel the air, which rendered it ſo light in appearance, and reduce it to it's real ſpecific gravity. That this is the fact may be ſeen by holding a piece of very dry cork under water, when the air, then expelled, will aſcend to the ſurface in bubbles.

The uſe of cork for the purpoſe of ſwimming has long been known. Among the ancients it was conſidered as an accompliſhment, *ſine cortice natare*, to ſwim without corks: on the other hand, not to be able to ſwim was ranked with not having learned to read. *Nec literas nec natare ſcire*, was a proverbial expreſſion for a man completely ignorant: the man, who could neither read nor ſwim, it was ſuppoſed, could know nothing.

Cork is not only light, but very conveniently applicable to the purpoſe, as it is eaſily cut into any ſhape, and is neither hard nor unpliable. It may be uſed in various ways. Whole pieces may be taken, and made into a ſort of cuiraſs: or it may be cut into ſlips, and theſe ſtitched between two *pieces of linen*, cotton, or flannel, ſo as to make *a waiſtcoat*. Theſe are the beſt modes of

uſing it; but the moſt common is, to take a few pieces of cork, ſtring them on a cord, and confine them by tying a knot at each end. The ſwimmer lays his breaſt on the middle of this cord, in ſuch a manner, that the corks, equally divided, lie juſt behind the armpits. A broad belt, however, is better for this purpoſe than a cord, as it will be leſs uneaſy to the ſwimmer: but, whichever of theſe is uſed, there ſhould be another cord or belt faſtened to the middle of it, forming a loop to go round the neck, that the corks may not ſlide down under the belly, which would imminently endanger the ſwimmer's life.

How much cork is neceſſary, to enable a man to ſwim?

This of courſe muſt depend on the ſpecific gravity of the perſon, and his abſolute weight; from which, if they be known, and the ſpecific gravity of cork, an anſwer to the queſtion may eaſily be found. That my young readers may know how to anſwer ſimilar queſtions themſelves on occaſion, I will ſtate a caſe for their inſtruction.

Suppoſe the perſon, when immerſed in *water up* to the neck, occupies the ſpace of

two cubic feet: he will then loſe as much of his own weight as equals the weight of two cubic feet of water, or 123 pounds. Allow his abſolute weight to be 135 pounds; and the ſpecific gravity of cork to be one fourth of that of water. The weight of the cork required we will repreſent by x. The young reader muſt not be ſtaggered at the algebraic mode of notation by letters and ſigns; for, inſtead of rendering things difficult and myſterious, it makes them eaſy and evident, as ſoon as their *ſignification* is underſtood.

Now the x lbs. of cork, when wholly immerſed, will diſplace $4x$ lbs. of water; and the weight of the perſon and the cork, $135+x$, muſt equal that of the water diſplaced by both, $123+4x$, in order that the perſon may ſwim as required. Hence we have the following equation.

$$123+4x=135+x.$$

Conſequently $123+3x=135$.

Therefore $3x=135-123=12$.

Whence we find $x=4$.

Four pounds of cork, therefore, will keep ſuch a perſon from ſinking, ſo that he will remain *with* his head completely above *water*.

The ſecond claſs of artificial helps for ſwimming are ſuch as ſupport the body by their figure, that is, by being hollow, ſo as to include air within them.

Of theſe the principal are bladders. Theſe are ſo far convenient, that a pair may be carried with eaſe in the pocket, while not inflated; and when the perſon arrives at the water's ſide, he may ſoon blow them up, and put them on. They are uſed in the ſame manner as corks; the caution given above reſpecting which is equally neceſſary with them: but, like the reſt of this claſs, they are not ſo ſecure as cork, for a hole accidentally made in one of them, or the ſlipping of the ſtring, may deprive the ſwimmer of their aſſiſtance unawares. Indeed a perſon, who cannot ſwim tolerably well, ſhould on no account venture out of his depth with bladders. A learner, who finds it difficult to acquire the art of ſwimming, either from weakneſs or awkwardneſs, may find them of ſervice, to ſupport him in the water, till he is enabled by practice, to move his legs and arms with more effect and leſs fatigue: but *this he* may do equally well without going *out of his* depth, and then, if the bladders

be properly ſecured from ſlipping down below the breaſt, he will be ſafe from danger.

Inflated ſkins were uſed for ſwimming in ancient times. Livy ſpeaks of this, by the by, as a common practice among the Spaniards in thoſe days. Kepler's ſwimming girdle is made of leather, hollow, and inflated.

The aquatic ſhield propoſed by Wagenſeil is equally inſecure, and more incommodious, as it conſiſts of a hollow box of wood faſtened round the body.

Cork, indeed, is the beſt and moſt ſecure of all artificial helps, though not ſo convenient for carriage as bladders.

For thoſe, who can ſwim by the exertion of their own powers, all theſe helps are unneceſſary; unleſs in ſea voyages, when it would be prudent, perhaps, for every one, to provide himſelf with a cork waiſtcoat, that he might incur leſs danger in caſe of ſhipwreck.

On this occaſion we muſt not omit the ſimple contrivance of the Chineſe; which conſiſts of four pieces of thick bamboo, about two feet long each, tied together at a little diſtance from the ends, ſo as to form a ſquare opening in the middle, through which the

head, and arms are thruſt. Theſe are then ſecured from ſlipping down, and will ſupport a perſon in the water effectually.

CHAP. XXXVIII.

OF THE DIVING-BELL.

As we ſometimes find it neceſſary, to ſupport ourſelves on the ſurface of the water, there are other occaſions, on which it would be convenient for us, to ſtay ſome time beneath. But a man cannot remain under water, without being ſuffocated, longer than he can diſpenſe with taking breath. By practice from an early age, a perſon may acquire a capacity of remaining under water for a few minutes, without injury: and it is well, to acquire this capacity, as it may be uſeful on many occaſions.

But as this capacity in general can be acquired only to little extent, it is much more convenient for a man, to deſcend into the ter ſurrounded by air, ſo that he may

continue there to breathe as uſual. Hence long ago attempts have been made, to contrive means of deſcending under water, without danger of being drowned, and even of doing many things in that ſituation. The poſſibility of ſuch a proceeding may be ſeen by an experiment eaſy to be made, which probably firſt led to the invention, in modern times ſo celebrated, under the name of the *diving-bell.*

Take a ſhort bit of wax taper, ſtick it on a piece of cork, light it, and ſet it on the ſurface of a bucket of water. Invert a drinking glaſs, place it over the taper, and depreſs the glaſs, till the water covers it. You will ſee, that the water riſes a very little way in the glaſs, but the upper part of the glaſs will remain full of air, in which the taper, floating on the ſurface of the glaſs, will continue to burn, till the air is rendered incapable of feeding the flame.

What the drinking glaſs is in this experiment in little, the diving-bell is on a larger ſcale. This machine has been brought to a conſiderable degree of perfection in modern *days, though the* invention itſelf appears to *be of conſiderable* antiquity. Even Ariſtotle

mentions, that divers made uſe of a caldron, to enable them to remain longer under water. This, however, is not perhaps to be conſidered as an account of what might properly be called a diving-bell. The tranſlators of the greek original, indeed, have added, that the divers inverted the caldron over their heads, and thus deſcended into the water. But Ariſtotle himſelf does not expreſsly ſay this; his words ſeem rather to imply, that ſuch caldrons, full of air, were ſent down to the divers, when they had been ſome time under water, that they might take breath in them, and ſo recruit themſelves, to remain under water afreſh.

In the time of Charles the fifth, ſomething more preciſe on the ſubject occurs. Taiſnier, who was governor to the pages of that emperor, ſaw an experiment at Toledo, in 1538, which two greeks performed in the preſence of that emperor, and which he deſcribes in the following manner.

"If the ignorant vulgar were told, that a perſon could deſcend amid the waves of the Rhine to the bottom of the river, *without wetting* his clothes, or any part of his *body*; nay that he could bring up fire burn-

ing through the water; they would laugh at the narrator, and declare it to be impoſſible. Yet this I myſelf ſaw, in the year 1538, in the ſpaniſh city of Toledo; where the experiment was made in the preſence of the emperor Charles the fifth, and near ten thouſand ſpectators, by two greeks. Theſe men took a large caldron, inverted it, and ſuſpended it by a rope. In the cavity of it they fixed croſs pieces of wood, to ſupport themſelves and the fire. Round the rim of the caldron they faſtened pieces of lead, which were equally diſtributed, ſo that the caldron hung evenly balanced, with the brim in a horizontal poſition. This was done, that one part might not touch the water ſooner, or with more force than another; otherwiſe it might eaſily have happened, that the water would overpower the air included in the caldron, and reſolve it into a fluid.*

* It appears, that the writer of this account had very erroneous ideas on this ſubject. The fact is, if one ſide of the veſſel were heavier than the other, the brim would touch the water obliquely, and ſo include leſs air, becauſe the air would have a free paſſage out, till the higher part of the brim was immerſed. *Beſides, the veſſel not* being exactly balanced, the upward *preſſure of the air*, in deſcending, would be ſtronger

If, however, the caldron, thus prepared, be let down into the water with ſufficient ſlowneſs, the air, encloſed in it by means of the water, will make itſelf room. Accordingly, the men in the machine will remain perfectly dry amid the water, till the included air is weakened by repeated breathing, and converted into aleſs ſubtile fluid, being abſorbed by the denſe moiſture of the water.* If, however, the caldron be ſlowly drawn up

againſt the higher ſide, than againſt the lower, which would be more perpendicular; ſo that it would raiſe the higher ſide ſtill more, and thus let more air eſcape, till the veſſel would be completely overturned, and filled with water.

* Here again Mr. Taiſnier is miſtaken. The air is not converted into a denſer fluid, but rendered unfit for breathing in a different way. The air of our atmoſphere is not a ſimple ſubſtance, but a compound; and it is only one of it's conſtituent parts that is capable of ſupporting life. Every time we breathe, a certain quantity of air is taken into the lungs. Theſe ſeparate from it that part, which is neceſſary to life, and expire the reſt. Thus by repeated breathing in a given quantity of air, the part neceſſary to life will be gradually conſumed, and the remainder will be totally incapable of ſupporting life; ſo that a perſon will as inevitably *die in it*, as if he were completely immerſed in water *alone*. It is to be obſerved, the ſame part of the air,

again in due time, the men will remain dry, and the fire unquenched."

So far this account, the oldeſt we have, of the important invention of the diving-bell. But this does not prove, who was the firſt perſon, that dived under water in a caldron, or other hollow veſſel: though we learn from it, that the contrivance was known in the ſixteenth century.

In the following century, we know, a machine on this principle was uſed, for the purpoſe of fetching up goods from the bottom of the ſea. When the ſpaniſh armada was defeated in 1588, ſome of the ſhips, that endeavoured to eſcape by paſſing round Scotland, were wrecked on the iſland of Mull. One of theſe, according to the report of ſome of the Spaniards, who were ſaved, had conſiderable treaſures on board. This ancient ſtory tempted perſons, from time to time, to make various endeavours for the recovery of the valuables, that were ſunk. In 1665, a perſon ſucceeded in bringing up a few guns,

which ſupports life, maintains combuſtion alſo; ſo that fire burning in a given quantity of air reduces it to *the ſame ſtate* as breathing in it.

but they did not ſufficiently repay the expenſe of the undertaking.

Some years after an attempt of the like kind was once more brought forward. William Phipps, the ſon of a blackſmith in America, propoſed to go down and unload a valuable ſpaniſh ſhip, which had been loſt on the coaſt of Hiſpaniola. His ſcheme appeared ſo plauſible to Charles II, that he furniſhed Phipps with a veſſel, and every thing requiſite to the undertaking. Accordingly, in 1683, he ſet ſail; but was unſucceſsful, and returned in great diſtreſs, though firmly convinced of the practicability of his deſign. He ſolicited another ſhip, therefore, from James II, who had now aſcended the throne. Having failed a ſecond time, he ſought to carry his enterpriſe into execution by the aſſiſtance of private individuals, and opened a ſubſcription for the purpoſe. At firſt he was laughed at; but at length the duke of Albemarle took up the affair, and advanced a conſiderable ſum of money, toward making the neceſſary preparations for a new voyage. Phipps ſoon procured the remainder, and *ſailed in 1687*, in a veſſel of two hundred tons,

try his fortune once more. At firſt all s attempts were in vain: but at length, hen his patience was nearly exhauſted, he ıcceeded in bringing up from the depth ſix or ſeven fathoms treaſure to the value three hundred thouſand pounds, with hich he returned ſafe to England. Of this e had about twenty thouſand pounds for is own ſhare; the duke of Albemarle had inety thouſand; and the reſt was divided mongſt the other ſubſcribers, in proportion o the ſums they had advanced. On his re-urn, ſome perſons would have perſuaded he king, to ſeize the ſhip and cargo; pre-ending, that Phipps did not give the king ı juſt account of the buſineſs, when he ſoli-cited his permiſſion for his voyage. James, however, nobly anſwered, that he knew Phipps to be an honeſt man; and that he and his owners ſhould ſhare the whole among them, were it as much again. Not ſatisfied with this, as a reward for his enterpriſing ſpirit, the king conferred upon him the honour of knighthood. Phipps was afterward raiſed to higher dignities, and died at London in 1693.

On this occaſion the duke of Albemarle

ſolicited from the king the poſt of governor of Jamaica, to get more out of other ſhips, that had been wrecked in thoſe parts. But, whether it were, that all the treaſure had been gotten out before, or that it had been diſperſed by the waves after the ſhips had gone to pieces, this is certain, that nothing was ever found of ſufficient value, to repay the labour of the ſearch.

From the ſucceſs of theſe trials, however, others were induced, to make ſimilar attempts in different places, though to little purpoſe. Of theſe, that excited moſt attention, which was made anew near the iſland of Mull, in 1688, on which occaſion the duke of Argyle was the principal perſon concerned. The divers went down to the depth of ſixty feet, remained there an hour at a time, and brought up golden chains, money, and other valuables, but all together to no great amount.

Since this period improvements have been made in the diving-bell, by Dr. Halley, Mr. Triewald, a Swede, and Mr. Spalding, of Edinburgh.

By Dr. Halley's improvement the water was kept entirely out of the bell at any depth, and the air ſpoiled by reſpiration

is exchanged for freſh air at pleaſure, ſo at the diver might remain under water as ng as he pleaſed. The following is his own count of the contrivance.

" The bell I made uſe of was of wood, conining about ſixty cubic feet in it's concavity; id was of the form of a truncate cone, e diameter of which at the top was three et, at the bottom five. This I coated ith lead, ſo heavy, that it would ſink empty; id I diſtributed the weight ſo about it's ottom, that it would go down in a perpenicular direction, and no other. In the top fixed a ſtrong but clear glaſs, as a window,) let in the light from above; and likewiſe cock, to let out the hot air, that had been reathed: and below, about a yard under the ell, I placed a ſtage, which hung by three opes, each of which was charged with about ne hundred weight, to keep it ſteady. This achine I ſuſpended from the maſt of a ſhip y a ſprit, which was ſufficiently ſecured by tays to the maſt-head, and was directed by races, to carry it overboard clear of the hip's ſide, and bring it on board again, as ccaſion required.

" *To ſupply* air to this bell when under

water, I cauſed a couple of barrels, about 56 gallons each, to be caſed with lead, ſo as to ſink empty; each of them having a bunghole in it's loweſt part, to let in the water, as the air in them condenſed on their deſcent; and to let it out again, when they were drawn up full from below. And to a hole, in the uppermoſt part of theſe barrels I fixed a leathern trunk, or hoſe, well liquored with bees-wax and oil, and long enough to fall below the bunghole, being kept down by a weight appended: ſo that the air in the upper part of the barrels could not eſcape, unleſs the lower ends of theſe hoſe were firſt lifted up.

"The air-barrels being thus prepared, I fitted them with tackle, proper to make them riſe and fall alternately, after the manner of two buckets in a well; which was done with ſo much eaſe, that two men, with leſs than half their ſtrength, could perform all the labour required: and in their deſcent they were directed by lines faſtened to the under edge of the bell, which paſſed through rings on both ſides the leathern hoſe in each barrel; ſo that, ſliding down by theſe lines, they came readily to the hand of a man,

o ſtood on the ſtage on purpoſe to re-
ve them, and to take up the ends of
: hoſe into the bell. Through theſe hoſe,
ſoon as their ends came above the ſur-
:e of the water in the barrels, all the air,
at was included in the upper parts of
em, was blown with great force into the
ll; while the water entered at the bung-
les below, and filled them: and as ſoon
the air of one barrel had been thus re-
ived, upon a ſignal given, that was drawn
), and at the ſame time the other deſcend-
; and, by alternate ſucceſſion, furniſhed
r ſo quick, and in ſo great plenty, that I
yſelf have been one of five, who have
:en together at the bottom in nine or
n fathoms of water, for above an hour
id half at a time, without any ſort of
conſequence: and I might have continued
ere as long as I pleaſed, for any thing that
peared to the contrary. Beſides, the whole
vity of the bell was kept entirely free from
ter, ſo that I ſat on a bench, which was
ametrically placed near the bottom, wholly
eſſed, with all my clothes on. I only ob-
:ved, that it was neceſſary to be let down
dually at firſt, as about twelve feet at a

time; and then to ſtop and drive out the water that entered, by receiving three or four barrels of freſh air, before I deſcended farther. But being arrived at the depth deſigned, I then let out as much of the hot air that had been breathed, as each barrel would repleniſh with cool, by means of the cock at the top of the bell; through the aperture of which, though very ſmall, the air would ruſh with ſo much violence, as to make the ſurface of the ſea boil, and to cover it with a white foam, notwithſtanding the weight of the water over us.

"Thus I found, that I could do any thing, that required to be done juſt under us; and that, by taking off the ſtage, I could, for a ſpace as wide as the circuit of the bell, lay the bottom of the ſea ſo far dry, as not to be over ſhoes thereon. And by the glaſs window ſo much light was tranſmitted, that, when the ſea was clear, and eſpecially when the Sun ſhone, I could ſee perfectly well to write or read; much more to faſten or lay hold of any thing under us, that was to be taken up. And by the return of the air-barrels, I often ſent up orders, written with an iron pen on ſmall plates of lead, directing

how to move us from place to place as occaſion required. At other times, when the water was troubled and thick, it would be dark as night below; but in ſuch caſes I have been able to keep a candle burning in the bell as long as I pleaſed, notwithſtanding the great expenſe of air neceſſary to maintain flame.

"By an additional contrivance, I have found it not impracticable for a diver, to go out of an engine to a good diſtance from it, the air being conveyed to him with a continued ſtream, by ſmall flexible pipes; which pipes may ſerve as a clew, to direct him back again, when he would return to the bell."

This ingenious contrivance of Dr. Halley, however, is liable to two inconveniences.—The raiſing of the bell depends entirely on the perſons on board the veſſel; and as it has a very conſiderable weight, even when in water, it requires a great deal of labour: but when it comes to be raiſed out of the water, the ſtrain upon the ropes is very great, and if they ſhould break, the perſons in the bell muſt inevitably periſh. Beſides, the bottom of the ſea is in many places rendered uneven by rocks; and if one of t'

edges of Dr. Halley's bell ſhould light upon a rock, the bell would infallibly be overſet before a ſignal could be made to the perſon above.

To obviate theſe dangers, Mr. Spalding took a very ſimple, eaſy, and ingenious method. His bell, like Dr. Halley's, is a truncated cone of wood, but not coated with lead. Round the lower part are ſuſpended leaden weights, ſufficient to keep the mouth of the bell always parallel with the ſurface of the water, whether the whole machine be heavier or lighter than an equal bulk of water, but not ſufficient to ſink the bell. To effect this, another weight is added, which is ſuſpended from the centre of the bell in the inſide by a pulley, ſo that it can be raiſed or lowered at pleaſure by the perſon within. Thus it is obvious, that, if the ropes above break, or the machine ſhould be in danger of being overturned by a projecting rock at the bottom of the ſea, the perſon or perſons within may immediately ſtop it's deſcent, or allow it even to riſe to the ſurface, by lowering the weight appended to the pully.

Unfortunately, in June, 1783, Mr. Spalding went down in Dublin bay, with another gentleman, to ſurvey the wreck of an imperial Eaſtindiaman, ſunk in ſeven fathom water, when they both periſhed. As they had been down three times the day before, the fatal accident was probably owing to their not being duly ſupplied with air by their aſſiſtants above, who were certainly negligent, for it appeared afterward, on a legal examination into the affair, that the ſignal ropes were entangled.

CHAP. XXXIX.

OTHER CONTRIVANCES FOR DIVING.

DIFFERENT perſons, at various times, have invented other means, to enable them to remain under water, but not equally uſeful and effectual with the diving-bell, though they deſerve to be briefly noticed.

We read, that the divers in the Mediterranean *uſed to take* in their mouths a ſponge

ſoaked in oil, to enable them to remain longer under water. At leaſt ſo it is ſaid; though it is very probable, that the oil was for the purpoſe of ſmoothing the water over them, to enable them to ſee objects clearly.

In Vegetius's book on the Art of War are ſome figures by the editor, but not explained in the work itſelf. Among theſe one repreſents a method of catching fiſh with the hand at the bottom of the ſea. The diver has his head incloſed in a caſe, which will not admit water; and to the caſe is annexed a long leathern pipe, the aperture of which floats on the ſurface, ſo that the diver may take breath through it. Little, however, can be expected from a contrivance like this, particularly where the depth is conſiderable.

Another contrivance, which ſeems to be an improvement on the former, conſiſts, like it, of a caſe for the head, but furniſhed with two tubes, both opening above the water. Through one of theſe freſh air is blown in by means of a pair of bellows, while the ſpoiled air is let out through the other; ſo that a circulation is kept up, by means of

which the diver has a conſtant ſupply of good air in his cap. This too can be of little ſervice, eſpecially in great depths: though the plan ſeems not altogether erroneous, and perhaps might be united with that of the diving-bell, as by Dr. Halley, to ſome advantage. The pipes, it is true, muſt be of conſiderable length, not too ſmall, and kept diſtended by ſome means, as by rings at ſhort diſtances on the inſide, to prevent the preſſure of the water from cloſing up the paſſage.

A ſcheme not different in principle, indeed, from the diving-bell, may be ſeen in a book on fortification, written by an italian, named Lorini, and publiſhed in the beginning of the ſeventeenth century. This machine conſiſts of a ſquare box, caſed with iron, and furniſhed with windows, and a ſeat for the diver.

The method adopted by a gentleman of Devonſhire appears to be ſuperiour to any of theſe, and on ſome occaſions perhaps preferable to the diving-bell itſelf. He has a large caſe of ſtrong leather, perfectly waterproof, which will hold about half a hogſhead of air. This is ſo contrived, that, when ſhut up in it, he can walk at the bottom of

the ſea, go into any part of a veſſel, that is wrecked, and take out the goods. By means of this machine, which he has uſed for a number of years, he is ſaid to have acquired a large fortune.

But all theſe experiments are trifling in magnitude compared with that of Cornelius Drebbel, who, about two centuries ago, conſtructed a veſſel, which was rowed along under water in the Thames, with ſeveral perſons on board. And it was but in the year 1774, that a mechanic of the name of Day had a ſhip built at Plymouth, in which he went down under water, and, after ſtaying twelve hours, roſe again, by letting looſe ſome weights, that were faſtened to the ſhip's bottom. On a ſecond trial, however, in twenty-two fathoms water, Mr. Day was not ſo ſucceſsful: for, whether the ſhip were overturned by the unevenneſs of the bottom, ſo that he could not diſengage the weights; whether the machinery were injured, ſo that it would not take effect; or whether any thing happened to himſelf within, as faintneſs, or drowſineſs, that rendered him unable *to act*; he periſhed at the bottom of the ſea, *the ſhip* never appearing again.

CHAP. XL.

ACCOUNTS OF SWIMMERS AND DIVERS.

THE people of the South-Sea iſlands, with whom we have become acquainted through the means of modern voyagers, are particularly expert in ſwimming and diving. At Otaheite men and women ſwam off to the ſhips, which lay out at ſome diſtance from the ſhore, and ſported about them like amphibious animals. Beads, nails, and other ſmall heavy bodies, thrown out of the ſhip into the ſea, they caught before they reached the bottom. They ſeem, indeed, to be nearly as much in their own element in the water, as on land: the children are accuſtomed to it from an early period, learn to ſwim almoſt as ſoon as to walk, and acquire ſuch dexterity by daily practice, that they can continue on the water for hours together.

When Surville, a celebrated french navigator, was at the Baſhee iſlands, in 1769, he detained ſeveral of the natives as priſoners, on account of ſome miſunderſtanding, that

aroſe. The ſailors tied their hands behind their backs, and were conducting them to the captain's cabin; when ſome of them had the boldneſs, to leap into the ſea, bound as they were; and, to the aſtoniſhment of the french, they ſwam in this manner to one of their canoes, which was at ſuch a diſtance, as to have nothing to fear from the ſhips.

At the Sandwich iſlands the principal perſons had in their ſervice particularly expert divers, to be employed by them on neceſſary occaſions. In 1788 our ſeamen had a proof of the ability of the divers of the king of Owhyhee. Their cable having parted, they had loſt the anchor in a con-
depth of water, and requeſted the
nd his divers to ſearch for it. They
d prepared themſelves for the en-
by certain ceremonies. Their canoes
g come to the place where the anchor
was ſuppoſed to lie, one of the chiefs diſ-
tributed a portion of taro roots, in calebaſhes,
ſix men, who were about half an hour
ng it. Another then gave three loud
outs, and waved a white cloth over his
ead. At this ſignal, the ſix men leaped into

the ſea, and diſappeared. Four of them came up again in about five minutes. The fifth remained one minute longer, and was nearly exhauſted when he roſe to the ſurface; but two men immediately caught hold of him, and lifted him into the canoe. Still there was nothing to be ſeen of the ſixth, and he was given over for loſt, when he appeared for a moment, but immediately ſunk again. Three of the divers leaped inſtantly after him, and brought him up ſenſeleſs. The blood guſhed out of his mouth and noſe; but after a time he recovered, and ſaid, that he had found the anchor, and loofened the cable from it. He had been ſeven minutes and half under water. The anchor lay too deep, to be gotten up; the divers, however, were amply rewarded for their trouble.

A few days after another anchor was loſt, and recourſe was had to the king's divers again. The former ceremonies were repeated, and they leaped into the water as before. On this occaſion neither of them remained more than four minutes under water, and the anchor was not found. They were ſent down a ſecond time, but with no better ſucceſs. At length the ſeamen hooked the

walk more ſteadily under the waves. He alſo ties another very heavy ſtone to one foot, which carries him ſpeedily to the bottom of the ſea. As the muſcles in general adhere firmly to the rocks, his hands are uſually defended with leathern gloves, to prevent them from being wounded, in tearing off the firſt; or elſe he is provided with an iron rake for the purpoſe. He likewiſe carries down with him a large net, hung round his neck by a cord, the other end of which is faſtened to the ſide of the veſſel. This net is to hold the muſcles gathered from the rock; and the cord is to pull up the diver, when his net is full, or when he wants air.

Thus equipped, he dives ſometimes to the depth of ſixty feet; and, as he has no time to loſe, as ſoon as he arrives at the bottom, he runs from ſide to ſide, tearing up all the muſcles he finds, and cramming them into his net.

At whatever depth the diver is, the light is ſo great, that he eaſily ſees whatever paſſes in the ſea; and ſometimes to his great conſternation, he perceives monſtrous fiſhes, from which his utmoſt addreſs, in muddying the water, &c. cannot always ſave him; ſo that

he unhappily becomes their prey. Of all the dangers of the fiſhery, this is one of the greateſt, and moſt uſual.

The beſt divers will keep under water near half an hour, and the reſt do not ſtay leſs than a quarter. During this time they hold their breath without the uſe of oils, or any other liquors, only acquiring the habit by long practice. When they find themſelves in want of air, they pull the rope, to which the bag is faſtened, and hold faſt by it with both hands. On this ſignal, the men in the veſſel draw them up by the rope, and unload them of their muſcles, which may be ſometimes five hundred, at others not above fifty. Some of the divers require a ſhort reſpite, to recover breath; others jump in again immediately, and continue this violent exerciſe for ſeveral hours without intermiſſion.

Thus we find it is by no means uncommon, where the art of diving is purſued with ardour, to find men capable of remaining under water for fifteen minutes, or even half an hour; or of diving to the bottom, and performing things there, at the depth of a hundred and twenty feet, or more. But it

is ſaid, that there have been people, capable of ſtill more than this. The moſt remarkable inſtance we have, at leaſt in which any confidence can be placed is that of the famous Sicilian diver, Nicolo Peſce. The authenticity of the account, indeed, depends on the authority of father Kircher; who aſſures us, that he had it from the archives of the kings of Sicily. Undoubtedly there is a little exaggeration in ſome parts of the tale, yet upon the whole it is certainly far from incredible. The following is Kircher's narrative.

" In the time of Frederick king of Sicily, there lived a celebrated diver, whoſe name was Nicholas; and who, from his amazing ſkill in ſwimming, and capacity of continuing under water, was ſurnamed the *Fiſh*. This man had been uſed to the ſea from his infancy; and earned his ſcanty ſubſiſtence by diving for corals and oyſters, which he ſold to the villagers on ſhore. His long familiarity with the ſea at length brought it, to be almoſt his natural element. He was frequently known to ſpend five days in the midſt of *the waves*, without any other proviſion than the *fiſh*, which he caught there, and ate raw.

He often ſwam over from Sicily to Calabria, a tempeſtuous and dangerous paſſage, carrying letters from the king. He was frequently known to ſwim among the gulfs of the Lipari iſlands, not in the leaſt apprehenſive of danger.

" Some mariners out at ſea one day obſerved ſomething at a diſtance, which they regarded as a ſea-monſter; but upon it's approach, it was known to be Nicholas, and they took him into their ſhip. When they inquired, whither he was going in ſo ſtormy and rough a ſea, and at ſuch a diſtance from land, he ſhowed them a packet of letters, which he was carrying to one of the towns of Italy, ſafely encloſed in a leathern bag, ſo that they could not be wetted by the waves. He kept them company for ſome time, converſing, and aſking them queſtions; and after eating a hearty meal with them, he took his leave, jumped into the ſea, and purſued his voyage.

" Nature ſeemed to have aſſiſted his powers of continuing on the deep in an extraordinary manner; for the ſpaces between his fingers and toes were webbed, as in a goose, *and his cheſt* became ſo very capacious, that

he could take in, at one inſpiration, as much breath as would ſerve him for a whole day.

"The account of ſo extraordinary a perſon did not fail, to reach the king himſelf; who commanded Nicholas, to be brought before him. It was no eaſy matter, to find Nicholas, who generally ſpent his time in the ſolitudes of the deep; but, at laſt, after much ſearching, he was found, and brought before his majeſty. The curioſity of the monarch had long been excited by the tales he had heard of the bottom of the gulf of Charybdis; and he now conceived, that it would be a proper opportunity, to obtain more certain information. He therefore commanded the poor diver, to examine the bottom of this dreadful whirlpool; and as an incentive to his obedience, he ordered a golden cup to be flung into it. Nicholas was not inſenſible of the dangers, to which he was expoſed, dangers beſt known to himſelf, and therefore he preſumed to remonſtrate: but the hopes of the reward, the deſire of pleaſing the king, and the gratification of ſhowing his ſkill, at laſt prevailed. He leaped *into the* gulf, and was inſtantly ſwallowed up *in it's bolom.* For three quarters of an hour

he continued under-water; during which the king and his attendants remained on ſhore, anxious for his fate. At length he appeared, holding the cup triumphantly in one hand, while with the other he made his way through the waves. It may be ſuppoſed, he was received with applauſe, when he came on ſhore: The cup was made the reward of his adventure; the king ordered proper care to be taken of him; and, as he was ſomewhat fatigued and debilitated by his labour, after a hearty meal he was put to bed, and permitted to refreſh himſelf by ſleeping.

"When he had thus recruited his ſpirits, he was again brought before the king, to gratify his curioſity with a narrative of the wonders he had ſeen, and his account was to the following effect. After ſaying, that he would never have obeyed the king's commands, had he been appriſed of half the dangers, to which he expoſed himſelf, he added, that there were four things which rendered the gulf dreadful, not only to men, but even to fiſhes themſelves. Theſe were, 1, the force of the water burſting up from the bottom, which required great ſtrength to reſiſt: 2, the abruptneſs of the rocks, on

every ſide threatening deſtruction: 3, the force of the whirlpool daſhing againſt theſe rocks: 4, the number and magnitude of the polypi, ſome of which appeared as large as a man, and which, every where ſticking againſt the rocks, ſtretched out their fibrous arms, to entangle every thing, that came near them. Being aſked, how he was able, ſo readily to find the cup, that had been thrown in, he replied, that it happened to be thrown by the waves into the cavity of a rock, againſt which he himſelf was driven in his deſcent.

"This account, however, did not ſatisfy the curioſity of the king. Being requeſted, to venture once more into the gulf for farther diſcoveries, he at firſt refuſed: but the king, deſirous of having the moſt exact information poſſible of all things to be found in the gulf, repeated his ſolicitations; and, to give them ſtill greater weight, produced a larger cup than the former, to which he added a purſe of gold. Theſe temptations were too powerful for the unfortunate diver, he plunged again into the whirlpool, and was never heard of more."

As Nicholas was celebrated for his capacity

of remaining under water, Paul Moccia, a neapolitan prieſt, was famous for being totally incapable of diving. This man, though well made, was bulky and fat. He weighed two hundred and thirteen pounds avoirdupois; and it was found by Joſeph Dies, the mathematician, that this was twenty pounds and a quarter leſs than an equal bulk of water would have weighed. Thus it appears by the laws of hydroſtatics, as explained in a preceding part of this volume, that he would not ſink of himſelf, but ſwim upright like an hydrometer. He was ignorant of the property he poſſeſſed, till he was advanced in life, when he diſcovered it, on attempting to dive when bathing. He then made the experiment of letting himſelf float in the ſea, and found it ſucceed: and getting two divers, to drag him down under water by the feet, as ſoon as they let go, he roſe to the ſurface ſpontaneouſly, and remained with his head and ſhoulders above water. When the ſea was ſmooth, he could go about in it wherever he pleaſed, by ſlightly moving his hands; and he could eat and drink, read, write, or the like, in the water.

It is probable, that many fat perſons have

no greater ſpecific gravity than this italian; but as thoſe who are corpulent ſeldom take much delight in ſwimming, they remain ignorant of the faculty they poſſeſs.

CHAP. XLI.

VENTRILOQUISTS.

Most people are contented, to employ their faculties in the ordinary way, fully ſatiſfied, if they anſwer the purpoſes of common life; and have no conception of what may be effected, by aſſiduous cultivation, or bending them to any particular purpoſe. The dexterity acquired by various mechanics in the employments in which they are conſtantly engaged is aſtoniſhing to other people; and while moſt men unuſed to the water begin to ſtifle, if immerſed in it for half a minute, we find others have brought their lungs by practice, to diſpenſe with the *inhalation* of freſh air for half an hour.

Thus the lungs and vocal organs of the ven-

riloquiſt appear to be extraordinarily ſubſervient to his will; and we are the more ſurpriſed at his performances, becauſe few have thought it worth while, to cultivate a faculty, that is applicable to no uſeful purpoſe.

To form words, men uſually expel the air from the lungs through the windpipe with more force, than in ordinary breathing; and at the ſame time contract the glottis, or upper part of the windpipe, ſo that the air, iſſuing out at a narrower paſſage, occaſions a ſound, more or leſs loud, which is the voice. As the voice paſſes out through the mouth, it is variouſly modified by changing the figure of this cavity; which is effected chiefly by means of the tongue and lips: and thus articulate ſounds are produced, or words formed. If gentle breathing alone be employed, and modified by the tongue and lips, without contracting the glottis, and forcing out the air ſo as to produce a loud voice, it is called whiſpering. This whiſpering is more or leſs loud, according as the breath is emitted with more or leſs ſtrength: but it muſt iſſue with ſomewhat more force than in ordinary breathing, otherwiſe the ſound will not be audible. This we com-

monly find in young children, when they firſt attempt to whiſper; they move their lips, but no articulate ſound is heard.

In ſpeaking, the air iſſues chiefly through the mouth; yet partly, in articulating certain letters, through the noſe alſo. When the noſtrils are held cloſe, or accidentally ſtopped, we can ſpeak, though with a different tone. This tone, which is very diſagreeable when in a high degree, is called ſpeaking through the noſe: and not altogether improperly; for though the voice cannot iſſue through the noſe, when the noſtrils are cloſed, this ſound is formed in the noſe, whether the noſtrils be ſtopped or open. When this defect is avoided, the noſe conduces much to improve the tone of the voice; as any one will find, who firſt pronounces a ſentence clearly and deliberately with his noſtrils open, and then, ſtopping his noſtrils, ſpeaks the ſame words without ſuffering any breath to enter his noſe.

The mouth, however, is ſo eſſential to ſpeaking, that, though different ſounds may be made with the lips ſhut, no articulate *voice* can be produced, while the lips are *cloſe*. If, indeed, there be a ſmall aperture

left between the lips, ſo that the air can iſſue out between them, many words may be ſpoken intelligibly, though with no very harmonious tone: but it is perhaps impoſſible, to articulate ſome of the conſonants, without moving the lips more or leſs.

Sounds may be formed, and words uttered, not only when air is forced out through the mouth, but alſo when it is drawn in. This, however, is much more difficult.

There have been people, in different ages, whoſe internal organs of ſpeech were ſo flexible, and who had ſuch ſkilful command over them, that they have been capable of articulating, and holding converſations, without any movement of their lips being perceptible. In ſuch caſes it is obvious, that the ſound of the voice muſt differ from what it would be in the uſual way. Moſt commonly it would have a ſomewhat obſcure and hollow ſound, and hence was ſuppoſed by thoſe, who did not know how it was produced, to be formed in the belly. On this account ſuch people were miſtakenly called ventriloquiſts, or ſpeakers from the belly, and this name is ſtill retained.

The feats, that theſe people are ſaid to

have performed, ſeem much more ſurpriſing in the narratives given of them, than they are in fact, when the whole of the buſineſs is underſtood. Perhaps my young readers will be beſt enabled to form an adequate idea of the ſubject, by being firſt told what they have done, and then inſtructed how to account for the performance.

At Saint Germain-en-Laie, ten miles from Paris, lived a ſhop-keeper, whoſe name was Saint-Gille, a very ingenuous and honeſt man. At Martinico he had learned from an intimate friend the art of ventriloquiſm in the ſpace of a week, and had made himſelf a great maſter in it by practice. Of this faculty he made no ill uſe, neither did he employ it as the means of getting money: he uſed it only to divert himſelf and his friends, and made no ſecret of the talent he poſſeſſed.

The abbe de la Cappelle, having heard many wonderful things of this man, was deſirous of being convinced of the truth by means of his own ears. Procuring an introduction to Mr. Saint Gille, he expreſſed to *him his* wiſhes; and was taken by him into a *back* parlour, where they both ſat down

y a ſmall fire, with a table between them. he abbe fixed his eyes the whole time ſted- ſtly on Mr. Saint Gille, who entertained im for half an hour with laughable anec- otes, to which his art had given birth. n a ſudden the abbe heard himſelf called y his name and title, by a voice which emed to come from the roof of a neigh- ouring houſe. He was ſurpriſed, but ſoon ueſſed at the deception, and aſked Mr. aint Gille, whether he were not giving him ſpecimen of his art. He was anſwered nly by a ſmile, and looking toward the ouſe, from which the ſound appeared to roceed, a voice ſeemingly in the corner of e room called out "not there." In this anner the artificial voice played round him, eming to come from different diſtances, d various places; as the artiſt thought roper. Notwithſtanding the abbe was ful- prepared for this, and knew it to be the oice of a man ſitting oppoſite to him, the ception was ſo complete, that he could not ing his ſenſes to form a true conception of e place, from which the ſound actually ued. When Mr. Saint Gille diſplayed *art, he* appeared to be perfectly ſilent,

and not the leaſt alteration was viſible in his countenance. The abbe obſerved, however, that he turned his face a little, though with perfect eaſe, and no appearance of deſign, ſo that one ſide of it only was to be ſeen, when he ſpoke as a ventriloquiſt.

The following anecdotes are ſelected from many related of this gentleman.

Mr. Saint Gille, returning home from a place, to which he had gone on buſineſs, ſought ſhelter from an approaching thunder ſtorm in a convent. Finding the whole community in mourning, he inquired the cauſe, and was told, that one of their body had died lately, who was the ornament and delight of the whole ſociety. To paſs away the time, he walked into the church, attended by ſome of the friars, who ſhowed him the tomb of their deceaſed brother, and ſpoke feelingly of the ſcanty honour, they had beſtowed on his memory. Suddenly a voice was heard, apparently proceeding from the roof of the choir, lamenting the ſituation of the defunct in Purgatory, and reproaching the brotherhood with their lukewarmneſs and want of zeal on his account. The friars, as ſoon as their aſtoniſhment gave them

leave to ſpeak, conſulted together, and agreed to acquaint the reſt of the community with this ſingular event, ſo intereſting to the whole ſociety. Mr. Saint Gille, who wiſhed to carry on the joke, diſſuaded them from taking this ſtep; telling them, that they would be treated by their abſent brethren as a ſet of fools and viſionaries. He recommended to them, however, the immediate calling of the whole community into the church, where the ghoſt of their departed brother might probably reiterate his complaints. Accordingly all the friars, novices, lay brothers, and even the domeſtics of the convent, were immediately ſummoned, and aſſembled together. In a ſhort time the voice from the roof renewed it's lamentations and reproaches, and the whole convent, falling on their faces, vowed to make a ſolemn reparation. As the firſt ſtep they chanted a *De profundis* in full choir; during the intervals of which the ghoſt occaſionally expreſſed the comfort he received from their pious exerciſes and ejaculations in his behalf. When all was over, the prior entered into a ſerious converſation with Mr. Saint Gille; and, on the ſtrength of what had paſſed,

rabbits, than not take occaſion to draw your ſword."

As a rival to Mr. Saint Gille may be mentioned baron Ferdinand von Mengden, of Horde, a lieutenant colonel, and a man of great underſtanding, who reſided at Vienna about twenty years ago, and was celebrated for his ſkill in ventriloquiſm.

This gentleman had a little doll, the lower jaw of which the perſon who held it could ſet in motion at will, by an ingenious mechanical contrivance, ſo that it appeared as if talking. When he wiſhed to amuſe a company, he would hold a converſation with this doll, and jeſt with her, till commonly the doll would at laſt grow ſo impudent, that he would put her into his pocket, from which ſhe would complain bitterly to the company of his ſevere treatment.

Being once at the court of Bayreuth, he was amuſing the prince of Zweybrueck and ſome other perſons of rank with this puppet, who could not conceive, how he managed the buſineſs. An iriſh officer, who was preſent, was firmly perſuaded, it muſt be ſome *living* creature, that had been taught to *ſpeak in* this manner; if it were nothing

a day in the wood, in order to inveſtigate the truth of this relation.

Mr. Saint Gille, as may be ſuppoſed, was not omitted among the gueſts. Before he joined the company in the wood, he completely impoſed upon one of the learned deputies of the academy, who had parted from the reſt, and accidentally fell in with him on the way. Prepared as he was, and on his guard againſt all deception of the kind, he thought, without the leaſt ſuſpicion, juſt as Mr. Saint Gille came up to him, that he was called to come back in great haſte by Mr. de Fouchy, who was with the reſt of the company more than a hundred yards diſtant. His ſervant, too, heard the ſuppoſed call, told his maſter of it, and, turning toward the company, bawled out as loud as he could to Mr. de Fouchy, "yes, ſir!"

The company being ſeated at table, the ſpirit, who was previouſly acquainted with ſome private anecdotes relative to certain of the perſons preſent, began to make himſelf heard. Sometimes the voice ſeemed to deſcend *out of the* air overhead, at other times

riſe from the ground, being chiefly addreſſed to the counteſs de B—, to whom, as well as to the reſt of the ladies, it paid many compliments. This entertainment continued for a couple of hours. The counteſs, who perhaps might be a little inclined to credulity, was fully convinced, that it was the voice of a ſpirit; and was not a little vexed, when the deception was diſcloſed.

Another time Mr. Saint Gille went to take a walk in this ſame wood with an officer, who always carried his head very erect, and his cheſt projecting, with a ſtrutting gait, and never ſpoke a word, unleſs battles or ſieges were the ſubject of converſation. As they came to an open ſpot, a voice called out, ſeemingly from behind a tree: "it is not every one, who wears a ſword, that has the heart to uſe it."

"What impudent raſcal's that?" exclaimed the officer.

"Some bird-catcher, I dare ſay;" returned Mr. Saint Gille in his natural voice; "perhaps taking a neſt of young birds: but let us go on."

The officer ſhook his head, and looked very ſour.

" You dare not wait for me:" ſaid the voice from the tree.

" Yes, if you will ſhow yourſelf:" replied the officer, ſetting his hat, and laying his hand upon his ſword.

" What do you mean?" ſaid Mr. Saint Gille, in his natural voice, again, holding him back; " it is only ſome one, that wants to laugh at you."

" A valiant poſture is not always a ſign of courage:" rejoined the voice, which had ſeemed to deſcend from the ſummit of the tree, till now it was at the bottom.

" That's no bird-catcher;" ſaid the officer in a fury. " I'll make him repent his impudence."

With this he drew his ſword, and made a thruſt into the buſh, at the bottom of the tree, where he ſuppoſed the enemy to be concealed. A rabbit, that lay there, leaped out, and ran away.

" See," ſaid Mr. Saint Gille with a laugh, " what a hero you have put to flight! Why do you not ſee whom your enemy is, before you make your attack? but your head is ſo full of battles and bloodſhed, that, like don Quixote, you had rather fight with buſhes

ſides, at the diſtance at which he is ſeen, and by candle-light too, a ſlight motion of the lips would not be very eaſily perceptible.

It is to be obſerved, likewiſe, that the aſſiſtance of the eye is called in, to deceive the imagination. The ventriloquiſt has a puppet, with which he pretends to converſe. The ſpectator hears a man ſpeak in his natural voice. This ſpeech is anſwered in a different key, in a kind of ſqueaking tone. It is natural for the ſpectator, to refer this voice to another perſon, particularly as the performer's countenance remains unmoved, like that of one liſtening, not like that of a perſon ſpeaking. Now there is nothing but the puppet preſent, to which the ſpectator can refer the voice, and this it's ſhrillneſs [illegible] it to be wondered, therefore, that he hears the ſound come from the [illegible] ?

In this caſe, if the ventriloquiſt be ſufficiently maſter of his art, to ſpeak without moving or being ſeen to move his lips, nothing more is neceſſary: the ſpeaking voice will naturally ſeem to come from the puppet; the puppet and the man being cloſe to-

gether, the ſound may juſtly be conſidered as iſſuing from the ſame ſpot. Fitz-James, too, it is to be remarked, when in the eating houſe, took care to ſtation himſelf near the ſpot, from which the voice was ſuppoſed to iſſue; and this ſpot was a hollow, encloſed place, which, it may be preſumed, well ſuited his fictitious voice, iſſuing from a nearly cloſed mouth.

On other occaſions, as in the anecdotes related of Mr. Saint Gille, more ſkill on the part of the ventriloquiſt appears to have been requiſite; though a ſkill by no means unattainable. Sounds differ according to the diſtance from which they proceed, and the direction in which they ſtrike our ears: a ventriloquiſt, who can judge of the effects that diſtance and direction produce on ſounds, and has acquired a capacity of modulating his artificial voice accordingly, may produce almoſt any deception of this kind. Beſides, we are little uſed to remote ſounds, or rather to judge of them with any degree of accuracy; ſo that in this, as in moſt other things, our own ignorance and negligence promote our being deceived. Mr. Saint Gille's performers, too, were on one occaſion a ghoſt,

on another an aerial ſpirit; and the a
would naturally ſuppoſe, that ſuch ir
rial being muſt ſpeak in a tone ſon
different from that of the human voice,
would facilitate his taſk.

In moſt of theſe inſtances, as is ge
the caſe, it is chiefly our own ſenſe
deceive us: and hence we ſhould lear
to rely on them with too much confi
at the ſame time endeavouring, by att
and aſſiduous cultivation, to render tl
accurate as poſſible, that they may
too liable to miſlead us. The neglige
ſome with reſpect to the moſt comn
our ſenſes, is ſtrikingly depicted in the
ing tale of Eyes and no Eyes, in Ev
at Home; and thoſe, who would w
improve the different ſenſes, we woul
to Salzmann's Gymnaſtics for Youth, a
which we have before had occaſion tc
tion.

END OF THE SECOND VOLUME.

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